AK.

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1993 APPLICATIONS AND PRODUCT HIGHLIGHTS

Featuring:

- Flash Memory Programmers
- Portable Equipment Power Management
- Two Complete PC RS-232 Ports – One Chip, +5V Single Supply
- Remotely Powered Sensor Amp Using 1μA Op Amp
- Video, Power, and Channel Select Signals on a Single Coax
- DSP System Anti-Aliasing Filters
- ±18-Bit Serial Interface A/D Converter
- 3V Analog Circuits for Portable Applications

Other Data Books Available from Maxim:

- Maxim 1992 New Releases Data Book, Vol. I
- Maxim 1993 New Releases Data Book, Vol. II
- Maxim 1992 Applications & Product Highlights Book

Call toll free 1-800-998-8800 for free samples or literature sent within 24 hours.

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COMPANY BRIEF:

Markets: Precision Linear and Mixed Analog-Digital ICs

Products: 509 Analog ICs Including
284 Propietary Products

Sales: $23.3 Million Quarter Ending 6/30/92

Profitable: Last 25 Consecutive Quarters
Operating Profits Above 18% Last 18 Quarters
ROE Above 19% Last 19 Quarters



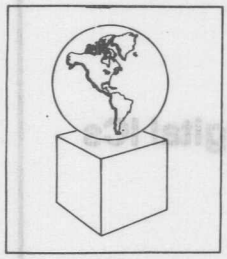
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REPEATED RECOGNITION AS ONE OF THE BEST

	6/30/91	6/30/92
Northern California Ranking SF Chronicle (Based on ROI)	35	23
Top California Companies LA Times	45	27
Forbes 200 Ranking	162	120
Repeat Companies		66 out of 88
Business Week 100 Ranking	67	83
Repeat Companies		26 out of 100

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MAXIM CHOSEN AS NICHE MARKET IC SUPPLIER OF THE YEAR FOR 1991



- DataQuest survey of purchasing management at top 250 electronics companies worldwide

DataQuest Inc.
Presents to
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MAXIM'S CLASS 10 FAB

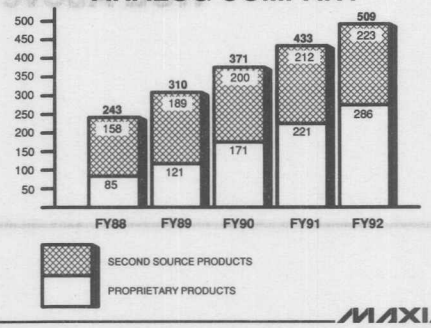
- State-of-the-Art Equipment
  - Steppers
  - Implant
  - RP Epi
  - Plasma Etch
  - PECVD
  - HIPOX
- Rejects <5%
- Tight Statistical Process Control
- Short Cycling Times
- Fabricating 5 Major Process Technologies
- Supplying 85% of Current Wafer Demand

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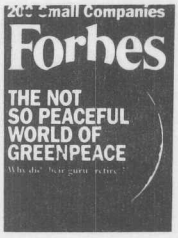
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MAXIM INTRODUCES MORE NEW PRODUCTS THAN ANY OTHER ANALOG COMPANY



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THE 200 BEST SMALL COMPANIES



How we define best

November 11, 1991

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GROWTH IN SALES PER QUARTER (MILLIONS $)

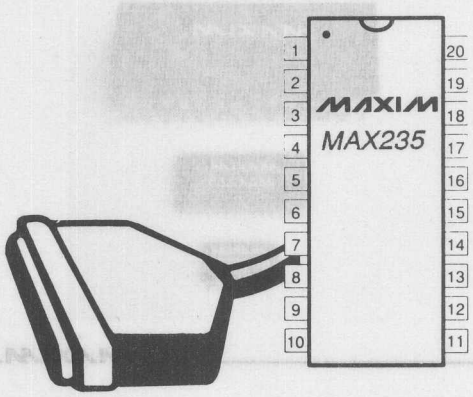


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INTERFACE

- Space-Saving Transceivers
- Low Power RS-232
- 3V RS-232 Transceivers
- Multiple Serial Ports
- Increased Data Rate
- RS-485/RS-422 Devices
- Display Drivers

A COMPLETE DTE INTERFACE



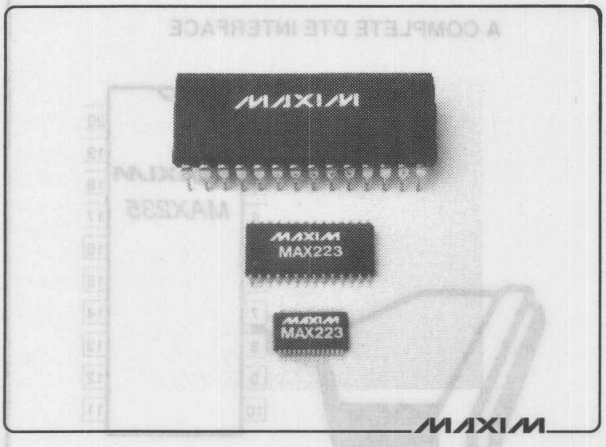
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WHAT DO YOU WANT IN A SERIAL INTERFACE?

COMPACTNESS: SMALL PACKAGES
MULTIPLE PARTS PER PACKAGE
SMALL CAPACITOR RANGE: 0.1 TO 1µF

LOW POWER: LOW OPERATING POWER
LOW POWER SHUTDOWN MODE
RECEIVERS ACTIVE IN SHUTDOWN MODE
SUPPLY VOLTAGE: 5V AND 3.3V VERSIONS

MAXIM



TWO RS-232 SERIAL PORTS ON A SINGLE CHIP

Device	No. of RS-232 Drivers	No. of RS-232 Receivers	External Capacitors	Shutdown & Three-State Outputs	Control Pins		Pin-Package
					Transmitter Enable	Receiver Enable	
MAX244	8	10	1µF	N	None	None	44 PLCC
MAX245	8	10	None	Y	$\overline{ENT}$ controls 8 Transmitters	$\overline{ENR}$ controls 8 Receivers, 2 Receivers always Active	40 PDIP
MAX246	8	10	None	Y	$\overline{ENTA}$ controls 4 "A" Transmitters & 4 "A" Receivers ENTB controls 4 "B" Transmitters & 4 "B" Receivers, 2 Receivers always Active		40 PDIP
MAX247	8	9	None	Y	$\overline{ENTA}$ controls 4 "A" Transmitters, ENTB controls 4 "B" Transmitters	$\overline{ENRA}$ controls 4 "A" Receivers, $\overline{ENRB}$ controls 4 "B" Receivers, 1 Receiver always Active	40 PDIP
MAX248	8	8	1µF	Y	$\overline{ENTA}$ controls 4 "A" Transmitters, ENTB controls 4 "B" Transmitters	$\overline{ENRA}$ controls 4 "A" Receivers, $\overline{ENRB}$ controls 4 "B" Receivers	44 PLCC
MAX249	6	10	1µF	Y	$\overline{ENTA}$ controls 3 "A" Transmitters, ENTB controls 3 "B" Transmitters	$\overline{ENRA}$ controls 5 "A" Receivers, $\overline{ENRB}$ controls 5 "B" Receivers	44 PLCC

MAXIM

Many designers today need compactness, low power, speed, and isolation. The consumer perceives small size and low power as attractive and more valuable. These perceptions extend to equipment that implements a serial interface.

Maxim offers a wide variety of packages for EIA-232 and EIA-562 parts. Included are 44 pin Plastic Leadless Chip Carrier (PLCC), 0.6inch DIP, 0.3inch DIP, wide and narrow Small Outline (SO), and the new Shrink Small Outline Package (SSOP).

Minimum power consumption is a frequent goal of serial interface designers. Power can be conserved in several ways. The first solution is to use a MAX220 that operates on only 10mW quiescent power, plus 16mW per transmitter used. Second, use devices that have a shutdown mode for applications where communication is intermittent. As the shutdown state becomes a larger percentage of the operation mode, the average power consumption decreases, down to the minimum of 10µA when shut down (MAX220).

The last approach is to use a circuit that operates from 3.3V supply. Devices that have the same number of transmitters and receivers but are designed to operate on 3.3V will consume about 1/4 the power of 5V powered parts. The majority of this power savings results from the decreased transmitter output voltage swing. Bear in mind that capacitive loading of the transmitters causes increased power consumption, especially at high transmission rates, so short cables help keep power consumption low. A graph showing power savings at various loads and data sheets is shown later, in the section on EIA-562 transceivers.

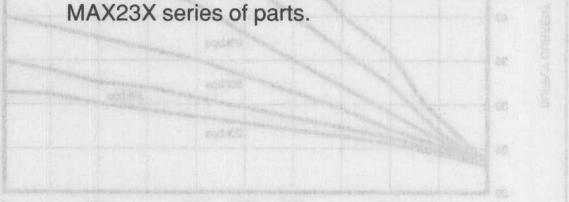
Maxim now offers devices in the new Shrink Small Outline Package (SSOP). Compare the old Small Outline (SO) to the new SSOP package: the new SSOP package occupies 43% of the area of a 28 pin SO package and only 14% of the area of a 28 pin 0.6 inch wide DIP.

Having many transmitters and receivers in one package facilitates building small pieces of equipment. The MAX244-249 are all capable of creating two complete EIA-232 serial interface ports. As single chips, they have more transmitters and receivers than parts from any other manufacturer. In addition, the transmitter outputs enter a high impedance condition when shut down. Specific receivers stay active in the shutdown mode to allow a remote system to reduce power and then be reactivated by external command. The receivers have an output enable / disable control to facilitate connection to a tri-state bus.

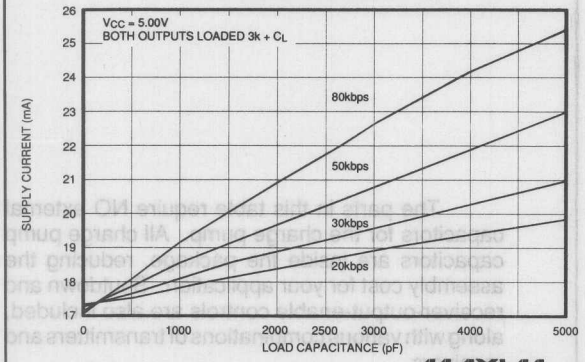
New Part Number	Number of RS-232 Drivers	Number of RS-232 Receivers	Guaranteed Min Slew Rate (V/µs)	Pins Per Package	Pin Compatible Upgrade For
MAX201	2	2	3	14	MAX231
MAX202	2	2	3	16	MAX232
MAX204	4	0	3	16	MAX234
MAX207	5	3	3	24	MAX237
MAX208	4	4	3	24	MAX238
MAX232A	2	2	6	16	MAX232

MAXIM

features. There is a variety of devices sharing the functionality and pin configurations of the original MAX23X series of parts.



MAX202 SUPPLY CURRENT vs. LOAD CAPACITANCE



MAXIM

A typical question is: "How much power or supply current is required for my serial interface?" Usually the answer is: "There are a several things to take into consideration before I can answer. For example, which part are you thinking of using? Will all the transmitters be used? What is the maximum data rate?" One question that also affects the supply current but has no fixed answer is: How much capacitance must be driven? This is usually beyond the control of the designer but it does deserve some thought, as supply current increases both with increasing data rate and with increasing capacitive load. The conditions for this graph for the MAX202 are: 5.0V supply voltage; both transmitters are loaded with 3kΩ.

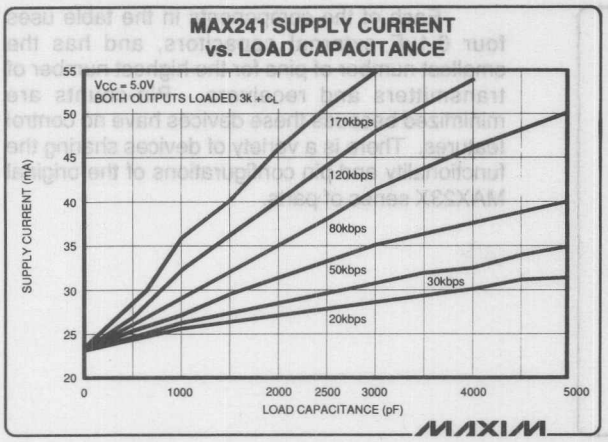
RS-232 TRANSCEIVERS THAT USE 0.1µF CAPACITORS

Devices With Control Inputs

Part Number	Number of RS-232 Drivers	Number of RS-232 Receivers	Guaranteed Min Slew Rate (V/µs)	Shutdown/ Three-State Controls	Pins Per Package	Pin Compatible Upgrade For
MAX200	5	0	3	Yes/No	20	MAX230
MAX206	4	3	3	Yes/Yes	24	MAX236
MAX209	3	5	3	No/Yes	24	MAX239
MAX210	5	5	3	Yes/Yes	44	MAX240
MAX211	4	5	3	Yes/Yes	28	MAX241
MAX222	2	2	6	Yes/Yes	18	LT1081
MAX242	2	2	6	Yes/Yes	18	

MAXIM

The parts in this table also use four small 0.1µF external capacitors for the charge pumps and have various combinations of transmitters and receivers. The new feature of this list is the use of control pins to shut down the charge pump or to put the receiver outputs into a three-state (high impedance) condition. The MAX222 controls both the charge-pump shutdown and the receiver output enable modes with a single pin. The MAX242 is similar, but with a separate control for each of these functions.



This graph shows the supply current requirements for the 4 transmitter MAX241. For the purpose of the test, each output is loaded with 3kΩ and all outputs are being driven at the same data rate. In practice, one driver generally transmits at a high data rate, and the others handle rather slower rates of control and handshaking information. When this is the case, the current consumption is significantly less than that shown in the graph.

Note that the MAX241 can easily accommodate the 116kbps data rate becoming popular with laptop-to-desktop PC communications, even in the unlikely event of long (high capacitance) cables being used.

The MAX223 (which has the same pin out as the MAX241, but with inverted control input polarity) allows 2 receivers to stay active in the shutdown mode, enabling the serial interface to listen for external activity while consuming minimal power.

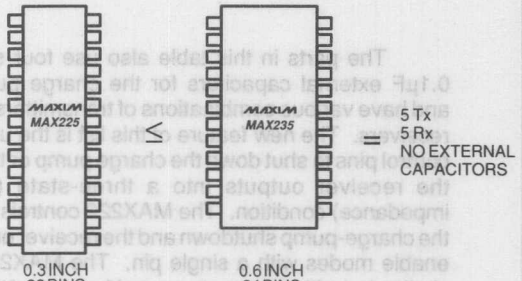
RS-232 TRANSCEIVERS THAT DON'T NEED CAPACITORS

Part Number	No. of RS-232 Drivers	No. of RS-232 Receivers	Guaranteed Min Slew Rate (V/µs)	Shutdown & Three-State Outputs	Packaging		Pin Compatible Upgrades For
					DIP Pins/Width mil.	SO Pins/Width mil.	
MAX225	5	5	5	Yes/Yes		28/300	
MAX203	2	2	3	No/No	20/300		MAX233
MAX233A	2	2	6	No/No	20/300	20/300	MAX233
MAX205	5	5	3	Yes/Yes	24/300		MAX235
MAX245	8	10	5	Yes/Yes	40/600		
MAX246	8	8	5	Yes/Yes	40/600		
MAX247	8	10	5	Yes/Yes	40/600		

MAXIM

The parts in this table require NO external capacitors for the charge pump. All charge pump capacitors are inside the package, reducing the assembly cost for your application. Shutdown and receiver-output-enable controls are also included, along with various combinations of transmitters and receivers.

HYBRIDS FOR SMALL SOLUTIONS



MAXIM

One of the benefits of incorporating the capacitors inside the package is that the pin-count can be reduced. For example, the MAX205 and MAX235 are in 24 pin packages, but would have to be in 40 pin packages if external capacitors were used. External capacitors take up a total of six pins. The MAX225 (which has the same functions as the MAX235) actually comes in a 28 pin package, but saves space by using a 0.3 inch wide DIP rather than the much larger 0.6 inch wide DIP.

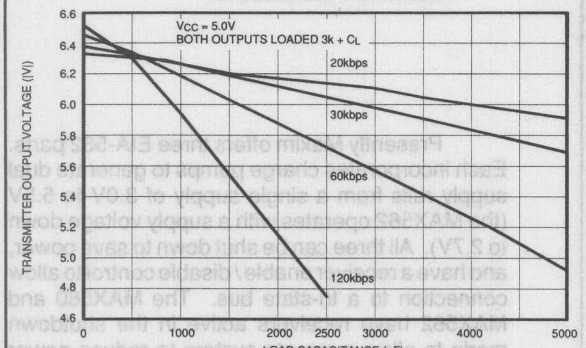
WHAT MORE DO YOU WANT IN A SERIAL INTERFACE?

SPEED: MEET AND EXCEED EIA-232/562 OFFICIAL LIMITS
GUARANTEED DATA RATE TO 116kbps
EIA-485/422 FOR HIGHER DATA RATES

ISOLATION: GROUND LOOP ELIMINATION
SAFETY
GRADES: 500V_{RMS}
1500V_{RMS} UL RECOGNIZED

MAXIM

MAX202 TRANSMITTER OUTPUT VOLTAGE vs. LOAD CAPACITANCE



MAXIM

CHOOSE A +3.3V TRANSCEIVER AND SAVE POWER

	+3.3V EIA-562 (MAX561)	+5V EIA-232 (MAX241)
Quiescent Power	27mW	75mW
Data rate	64kbps	20kbps
Tx Output Voltage, Min	±3.7V	±5V
Rx Input Threshold, Min	±3V	±3V
Rx Input Voltage, Max	±30V	±30V
Rx Input Resistance	3kΩ to 7kΩ	3kΩ to 7kΩ
Instantaneous Slew Rate	<30V/µs	<30V/µs

MAXIM

The EIA-232 and EIA-562 specifications apply to data rates of up to 20kbps when driving 2500pF, and EIA-562 allows data rates up to 64kbps when driving 1000pF. However, many people routinely use data rates above 100kbps, or drive capacitive loads of up to 5000pF. Several of Maxim's EIA-232 devices are guaranteed to operate at 116kbps with 2500pF loads, and drive 2500pF loads at 64kbps.

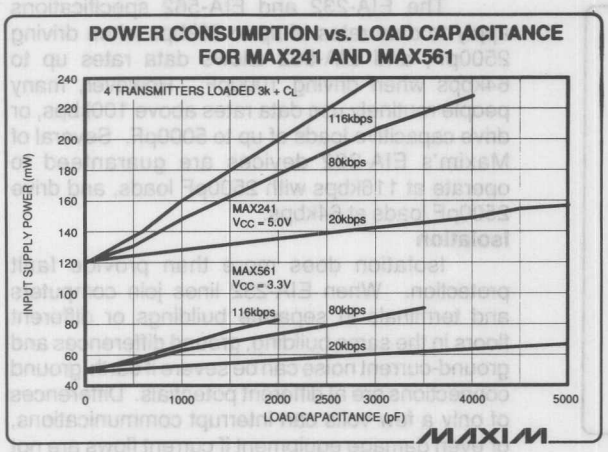
Isolation

Isolation does more than provide fault protection. When EIA-232 lines join computers and terminals in separate buildings or different floors in the same building, ground differences and ground-current noise can be severe if earth-ground connections are at different potentials. Differences of only a few volts can interrupt communications, or even damage equipment if current flows are not limited. Isolation eliminates this problem by level shifting from one potential to another.

Some sensitive analog electronic circuits can easily be upset by noise picked up by the EIA-232 cable. The cable acts as an antenna, and high frequency noise can find its way through the EIA-232 device, through the power supply, and into sensitive analog circuits. This noise can be dramatically attenuated by using a low capacitance isolation device, such as the MAX250/1/2 series, to prevent noise from the EIA-232 cable coupling back into the equipment.

As designers push the data rate above 20kbps they must remember that the power supply sections of these EIA-232 devices can only convert a limited amount of power. More power is required at higher data rates, and when higher capacitance loads are driven. As a result, higher data rates can be used only with lower capacitance loads, while more capacitance can be driven at lower data rates. The EIA-232 specification calls for 5V minimum at the transmitter outputs. If these outputs are less than 5V, you need to reduce the capacitive load, reduce the data rate, or choose a faster device.

Before the MAX232 was developed by Maxim, many quasi-232 interfaces were implemented with 5V power supplies. Output levels from these transmitters did not meet the letter of the EIA-232 law, but they worked well with light capacitive loads (short cable lengths) and were often used successfully at data rates above 20kbps. The success of these designs is owed mostly to EIA-232's 2V margin between its 5V minimum transmitter output specification (not met by 5V designs) and its 3V receiver input thresholds. In practice, most EIA-232 receivers will accept even TTL levels.



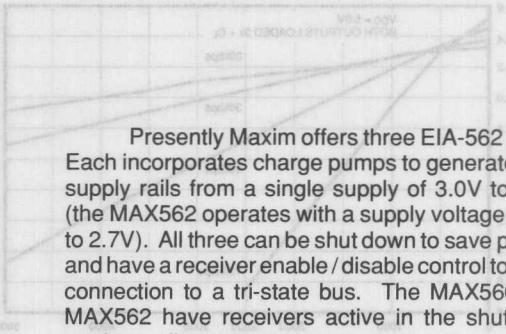
A new standard, EIA-562, has been written to cover these 5V circumstances. It differs from EIA-232 mainly in driver output levels and data rates. Not only does it form a useful standard in its own right, but it offers interoperability with EIA-232 interfaces. The use of lower driver output voltages and the same receiver input resistances (compared with EIA-232) offers the advantage of much lower power consumption to designers of portable equipment. It is often these portable computing devices that need higher data rates, and do not have long cables, making EIA- 562 the obvious choice.

The savings in power can exceed 50% when a +3.3V supply is used to power EIA-562 IC's. This graph illustrates how much power can be saved at three data rates up to 116kbps. As always, higher capacitive loads cause higher power consumption.

RS-562 TRANSCEIVERS

Part Number	Supply Voltage Range (V)	Number of RS-562 Drivers	Number of RS-562 Receivers	Number of Receivers Active in Shutdown	Shutdown/ Three-State Controls	Pins Per Package
MAX560	3.0 to 5.5	4	5	2	Yes/Yes	28
MAX561	3.0 to 5.5	4	5	0	Yes/Yes	28
MAX562	2.7 to 5.5	3	5	5	Yes/Yes	28

MAXIM



Presently Maxim offers three EIA-562 parts. Each incorporates charge pumps to generate dual supply rails from a single supply of 3.0V to 5.5V (the MAX562 operates with a supply voltage down to 2.7V). All three can be shut down to save power, and have a receiver enable / disable control to allow connection to a tri-state bus. The MAX560 and MAX562 have receivers active in the shutdown mode to allow a remote system to reduce power and then be reactivated by an external command.

ISOLATED RS-232 IN ONE PACKAGE
MAX252

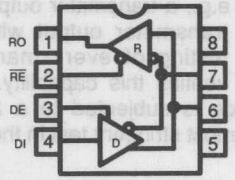
REDUCE COMPLEXITY

- No External Components
- 50µW Low Power Shutdown
- Single +5V Supply
- 2 Transmitters & 2 Receivers
- 1500V_{RMS} Isolation (1 second) – MAX252A



MAXIM

The original isolated RS-232 family comprises the MAX250/251 chip set, the 500V MAX252B, and the 1500V UL Recognized MAX252A. Contact Maxim for status on higher isolation voltage parts and VDE compliance.



- INDUSTRY STANDARD PINOUT, LOW POWER CMOS CONSTRUCTION
- MAX485: LOW POWER – 500µA WITH TX DISABLED
- MAX481: CONSUMES ONLY 10µA WHEN Tx AND Rx DISABLED
- MAX483: 3V/µs SLEW RATE FOR LOWER EMI & REFLECTIONS

LIMIT

MAXIM

DISPELLING THE MYTHS OF CMOS RS-232

- ESD
- LATCHUP
- DATA RATE
- DRIVE CAPABILITY

MAXIM

ESD PROTECTION GREATER THAN 4000V

- MAX230-241 FAMILY GREATER THAN 4000V
- MAX200-211 FAMILY GREATER THAN 4000V
- PROPRIETARY OUTPUT STRUCTURE

MAXIM

reflections are important.

The MAX485 incorporates the industry standard pinout, and operates on 500µA with the transmitter disabled. During transmission, the load presented by the 50Ω cable and termination dominate the power consumption.

The MAX481 is similar, but can be shut down completely, so that in very power-conscious applications the quiescent current drops below 10µA. Like the MAX485, the supply current is only 500µA when the receiver is active and the transmitter is shut down.

The MAX483 can be shut down to 10µA supply current, like the MAX481, but in addition the MAX483 draws only 200µA when the receiver is active and the transmitter is disabled.

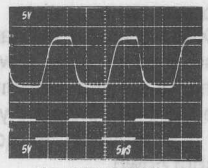
Although the RS-485 specification permits high data rates (up to 10Mbps), most RS-485 interfaces operate below 120kbps. High speed transmissions have rapid transition times (slew rates of up to 300V/µs), which easily generate Electromagnetic Interference (EMI). The MAX483's at 3V/µs slew rate substantially reduces EMI, but still allows data rates of up to 150kbps. And because we've used the industry standard pin configuration, the choice is yours.

Myths about CMOS RS-232 Interface devices have propagated since Maxim invented these products several years ago. Because of weaknesses in older CMOS technologies, it is sometimes assumed (and promoted by our competitors) that CMOS interface ICs are somehow inferior to bipolar with regard to reliability. As the following slides show, this is far from true. In addition, data rate and drive capability for CMOS are the highest in the industry.

Maxim's CMOS RS-232 device families excel in ESD protection. Several families' ESD stress ratings exceed 2000V; some exceed 4000V. This capability is brought about by a proprietary Maxim output structure. ESD testing to 2000V is done to 883 (Class B, Rev. C) standards using the human body model outlined in Method 3015.

FASTEST DATA RATES IN THE INDUSTRY

- **MAX230-241: 116kb/sec**
- **MAX200-211: 116kb/sec**
- **MAX222-243: 116kb/sec GUARANTEED**
- **MAX244-249: 116kb/sec**



V_{CC} = 5.00V, f = 58kHz
R_{LOAD} = 2.97kΩ AND 2500pF
DRIVING 3 TRANSMITTERS

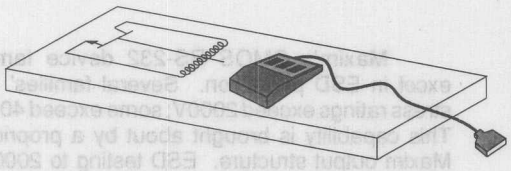
MAXIM

After ESD, the biggest concern of users of CMOS is latchup. Maxim CMOS RS-232 devices absolutely do not latch under both normal or fault conditions; e.g., a transmitter output can short to any other transmitter output without incident. Extensive testing of every manufacturing lot continually verifies this capability. Each pin of every device is subjected to a 200mA current stress, the most stringent test in the industry.

Maxim's original single-5V-supply RS-232 transceivers (introduced in 1985) were designed to meet the RS-232 20kb/sec data rate spec. Customer needs for higher speed have resulted in improvements allowing operation at 116kb/sec and above. Devices guaranteed to operate at 116kb/sec typically operate at 200kb/sec. No other RS-232 transceivers deliver higher performance.

DON'T TRAP YOUR MOUSE WITH BIPOLAR

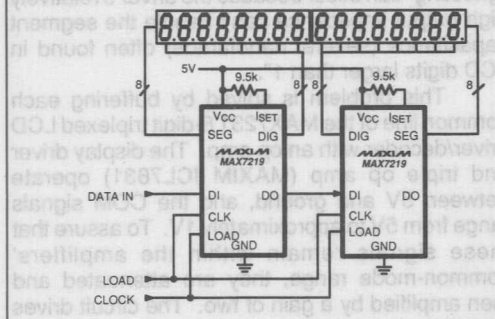
- **MAXIM'S CMOS – SUPERIOR DRIVE FOR MICE BIPOLAR V_{SAT} REDUCES OUTPUT VOLTAGE**
- **10mA AT 5V TRANSMITTER OUTPUTS**



MAXIM

CMOS charge pumps inside Maxim's 5V RS-232 tranceivers provide higher output voltages for powering mice than their bipolar counterparts. Bipolar charge pumps have an inherent loss due to internal transistor forward voltage drops. This frequently makes their output voltage inadequate at the current levels needed by even low-power mice. Maxim's charge pumps are made with low-resistance CMOS switches to easily meet the supply needs of mice.

MAX7219 7-SEGMENT 8-DIGIT DISPLAY DRIVER



MAXIM

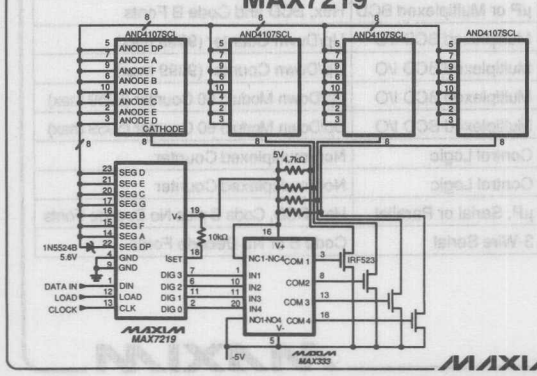
MAX7219: EASY INTERFACE FROM µP TO LEDs

- **3-Wire Serial Interface – Easily Cascaded**
- **Only One External Component (1 Resistor)**
- **8 Digits Plus DP, or 64 LEDs, or Combinations of Digits and LEDs**
- **Set Intensity Two Ways:**
  External Resistor
  Microprocessor Control
- **150µA Shutdown Mode**
- **Decode/No-Decode Display Modes**

MAXIM

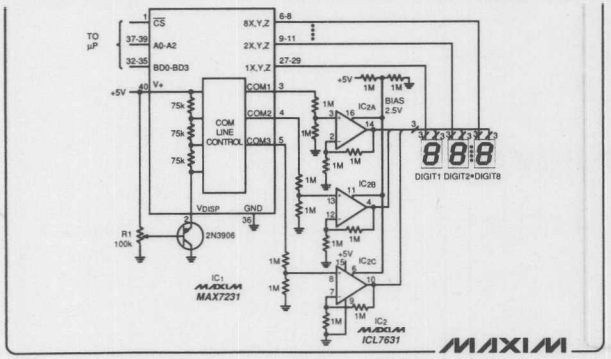
The MAX7219 7-Segment 8-Digit Display Driver includes a 3-wire serial interface, making it easy to use and easy to cascade for large displays. When data is sent to cascaded drivers, a No-Op (No-Operation) command allows selected drivers to remain unaffected while other ones are updated. Display intensity, set with an external resistor, is also digitally adjustable via the serial interface. A shutdown mode is also available, but the MAX7219 can still be programmed when shut down. Other features include a Decode/No-decode Mode and digital control of number of digits displayed (1-8). The MAX7219 can control 64 LEDs individually or numerous combinations of digits and discrete LEDs.

DRIVING 4 INCH LED DISPLAYS MAX7219



MAXIM

Large LED displays require much more power than conventional 0.3" seven-segment LEDs. As shown in the figure, driving large digits is not difficult with the MAX7219 because the segment drivers can source 40mA. A MAX333 quad SPDT switch level-shifts the MAX7219 drive signals to external digit-drive transistors. This accommodates the 8V forward drop of the display segments, which are formed by series-connected LEDs. The 1N5524B Zener diode is added to control decimal point intensity because the DP (only one LED) forward voltage is approximately 5V less than that of each segment.



ghosting can occur because the driver's relatively high output impedance can't handle the segment capacitance (several nanofarads) often found in LCD digits larger than 1".

This problem is solved by buffering each common line of the MAX7231 8-digit triplexed LCD driver/decoder with an op amp. The display driver and triple op amp (MAXIM ICL7631) operate between 5V and ground, and the COM signals range from 5V to approximately 1V. To assure that these signals remain within the amplifiers' common-mode range, they are attenuated and then amplified by a gain of two. The circuit drives eight 1-inch displays and is suitable for ambient temperature variations of 15°F or less. At the highest temperature, adjust R1 so that no "off" segments are visible.

MAXIM'S DISPLAY DRIVERS/COUNTERS

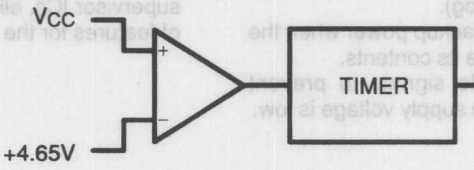
Part No.	Type	Drive Capability	Interface	Features
MAX7231	LCD	8 Digits (7-segment plus 2 annunciators)	6-Bit, Parallel	Triplexed
MAX7232	LCD	10 Digits (7-segment plus 2 annunciators)	µP, Serial	Triplexed
MAX7233	LCD	4 18-segment characters	6-Bit, Parallel	Triplexed
MAX7234	LCD	5 18-segment characters	µP, Serial	Triplexed
MM74C945	LCD	4 Digits (7-segment)	Control Logic	Non-multiplexed Up/Down Counter
MM74C947	LCD	4 Digits (7-segment)	Control Logic	Non-multiplexed Up/Down Counter
ICM7211	LCD	4 Digits (7-segment)	µP or Multiplexed BCD	Hex, BCD and Code B Fonts
ICM7212	C.A. LED	4 Digits (7-segment)	µP or Multiplexed BCD	Hex, BCD and Code B Fonts
ICM7217	C.A. LED	4 Digits	Multiplexed BCD I/O	Up/Down Counter (9999 max)
ICM7217A	C.C. LED	4 Digits	Multiplexed BCD I/O	Up/Down Counter (9999 max)
ICM7217B	C.A. LED	4 Digits	Multiplexed BCD I/O	Up/Down Modulo 60 Counter (5959 max)
ICM7217C	C.C. LED	4 Digits	Multiplexed BCD I/O	Up/Down Modulo 60 Counter (5959 max)
ICM7224	LCD	4 1/2 Digits	Control Logic	Non-multiplexed Counter
ICM7225	C.A. LED	4 1/2 Digits	Control Logic	Non-multiplexed Counter
ICM7218/ICM7228	C.A./C.C LED	8 Digits (7-segment plus 1 annunciator)	µP, Serial or Parallel	Hex, BCD, Code B plus No Decode Fonts
MAX7219	C.C. LED	8 Digits (7-segment plus 1 annunciator)	3-Wire Serial	Code B or No Decode Fonts

Note:
C.A. = Common Anode C.C. = Common Cathode

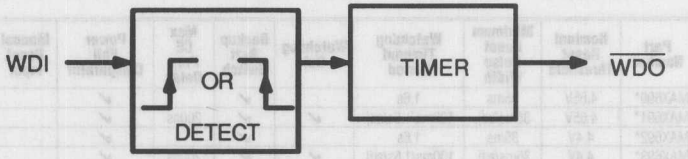
MAXIM

µP SUPERVISORS

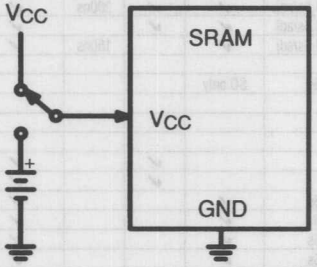
- **POWER LINE MONITORING**



- **WATCHDOG TIMER**



- **MEMORY BACKUP**



MAXIM

Supervisory circuits perform the "messy" analog monitoring and housekeeping functions required to keep a microprocessor (µP) circuit from malfunctioning. These features fall into three categories: power line monitoring, memory protection, and watchdog facilities. In detail, the functions include:

- Asserting reset during conditions of invalid µP supply voltage.
- Holding reset asserted for a minimum amount of time, typically 140ms, to allow enough time for the entire system to clear its state (allowing time for capacitors to discharge for example).
- Warning of main power fail by sensing the unregulated voltage fed to the main regulator.
- Detecting software infinite loops by resetting the system if an I/O line has not toggled within 1.6 seconds (watchdog).
- Switching RAM to backup power when the main power fails to preserve its contents.
- Gating chip-enable signals to prevent writing to memory when the supply voltage is low.

Different µPs require different flavors of supervision. For example, Motorola µPs tend to have active low $\overline{\text{RESET}}$ inputs while Intel µPs have active high RESET inputs. Motorola µPs like to have long reset pulse widths, about 100ms, while Intel µPs tolerate pulse widths less than 50ms. Early versions of the Motorola MC68HC11 required that $\overline{\text{RESET}}$ stay low even as V_{CC} fell to 1V.

The variety of memory technologies available also adds different requirements to memory backup. Static RAMs retain data with as little as 2V at 2µA applied to their V_{CC} pins, while most Pseudo Static RAMs (PSRAMs) need at least 4V at 100µA. PSRAMs, like DRAMs, need to be refreshed, requiring either an external clock or a signal that tells the PSRAM to refresh itself.

MAXIM provides a wide selection of µP supervisor ICs, allowing just the right combination of features for the particular µP used.

Part Number	Nominal Reset Threshold	Minimum Reset Pulse Width	Watchdog Timeout Period	Watchdog Out	Backup Batt Switch	Max CE Prop Delay	Power Fail Comparator	Manual Reset Input	Low Line Out	Active High Reset	Batt On Output	Pins	Max Supply Current
MAX690*	4.65V	35ms	1.6s		✔		✔					8 DIP	5mA
MAX691*	4.65V	35ms/adj.	100ms/1.6s/adj.	✔	✔	200ns	✔		✔	✔	✔	16 DIP, SO	5mA
MAX692*	4.4V	35ms	1.6s		✔		✔					8 DIP	5mA
MAX693*	4.4V	35ms/adj.	100ms/1.6s/adj.	✔	✔	200ns	✔		✔	✔	✔	16 DIP, SO	5mA
MAX694*	4.65V	140ms	1.6s		✔		✔					8 DIP	5mA
MAX695*	4.65V	140ms/adj.	100ms/1.6s/adj.	✔	✔	200ns	✔		✔	✔	✔	16 DIP, SO	5mA
MAX696	adj.	35ms/adj.	100ms/1.6s/adj.	✔	✔		✔		✔	✔	✔	16 DIP, SO	4mA
MAX697	adj.	35ms/adj	100ms/1.6s/adj.	✔		150ns	✔		✔	✔		16 DIP, SO	300µA
MAX698*	4.65V	140ms								SO only		8 DIP, 16 SO	5mA
MAX699*	4.65V	140ms	1.6s	SO only						SO only		8 DIP, 16 SO	5mA
MAX700	4.65V/adj.	200ms						✔		✔		8 DIP, SO	200µA
MAX701*	4.65V	200ms						✔		✔		8 DIP, SO	200µA
MAX702*	4.65V	200ms						✔				8 DIP, SO	200µA
MAX703	4.65V	140ms			✔		✔	✔				8 DIP, SO	350µA
MAX704	4.4V	140ms			✔		✔	✔				8 DIP, SO	350µA
MAX705	4.65V	140ms	1.6s	✔			✔	✔				8 DIP, SO	350µA
MAX706	4.4V	140ms	1.6s	✔			✔	✔				8 DIP, SO	350µA
MAX706R	3.08V	140ms	1.6s	✔			✔	✔				8 DIP, SO	350µA
MAX706S	2.93V	140ms	1.6s	✔			✔	✔				8 DIP, SO	350µA
MAX706T	2.93V	140ms	1.6s	✔			✔	✔				8 DIP, SO	350µA
MAX707	4.65V	140ms					✔	✔		✔		8 DIP, SO	350µA
MAX708	4.4V	140ms					✔	✔		✔		8 DIP, SO	350µA
MAX708R	3.08	140ms					✔	✔		✔		8 DIP, SO	350µA
MAX708S	2.93V	140ms					✔	✔		✔		8 DIP, SO	350µA
MAX708T	2.63V	140ms					✔	✔		✔		8 DIP, SO	350µA
MAX690A	4.65V	140ms	1.6s		✔		✔					8 DIP, SO	350µA
MAX691A	4.65V	140ms/adj.	1.6s/adj.	✔	✔	10ns	✔		✔	✔	✔	16 DIP, SO	70µA
MAX692A	4.4V	140ms	1.6s		✔		✔					8 DIP, SO	350µA
MAX693A	4.4V	140ms/adj.	1.6s/adj.	✔	✔	10ns	✔		✔	✔	✔	16 DIP, SO	70µA
MAX791	4.65V	200ms	1.6	✔	✔	10ns	✔	✔	✔		✔	16 DIP, SO	70µA
MAX1232	4.65V/4.4V	250ms	150/600/1200ms					✔		✔		8 DIP, 8/16 SO	200µA
MAX1259					✔							16 DIP, SO	3.3mA

* = Not recommended for new designs

MAXIM

ENHANCED VERSIONS OF THE MAX690 FAMILY

- Pin and Functionally Compatible with MAX690A-693A Family
- Low Supply Current
  - MAX690A/692: 350µA max
  - MAX691A/693A: 70µA max
  - MAX690A/692A: 350mA max
  - MAX691A/693A: 0.55Ω
- Low R_{ON} Switch Connects V_{CC} to V_{OUT}
- $\overline{RESET}$ Not Triggered When Backup Battery Removed
- Simple SuperCap™ Backup Circuit
- Guaranteed $\overline{RESET}$ Valid at V_{CC} = 1V
- Battery Voltages As High As V_{CC}-0.3V Allowed

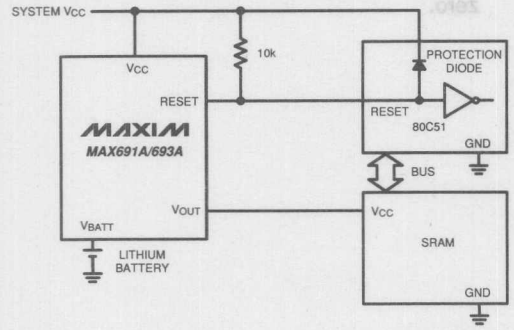
MAXIM

ENHANCED VERSIONS OF THE MAX690 FAMILY

- Pin and Functionally Compatible with MAX690-693 Family
- Low Supply Current
  - MAX690A/692A: 350µA max
  - MAX691A/693A: 70µA max
- Low R_{ON} Switch Connects V_{CC} to V_{OUT}
  - MAX690A/692: 5Ω
  - MAX691A/693A: 0.5Ω
- $\overline{RESET}$ Not Triggered When Backup Battery Removed
- Simple SuperCap™ Backup Circuit
- Guaranteed $\overline{RESET}$ Valid at V_{CC} = 1V
- Battery Voltages As High As V_{CCmin}+0.3V Allowed

MAXIM

SIMPLE 8051 INTERFACE



MAXIM

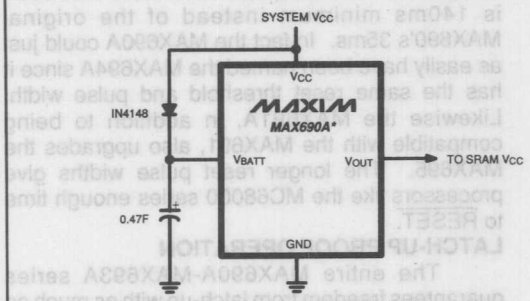
The MAX690A provides a number of enhancements to the MAX690 while remaining pin compatible. The reset pulse width of the MAX690A is 140ms minimum instead of the original MAX690's 35ms. In fact the MAX690A could just as easily have been named the MAX694A since it has the same reset threshold and pulse width. Likewise the MAX691A, in addition to being compatible with the MAX691, also upgrades the MAX695. The longer reset pulse widths give processors like the MC68000 series enough time to $\overline{RESET}$.

LATCH-UP PROOF OPERATION

The entire MAX690A-MAX693A series guarantees freedom from latch-up with as much as ±50mA of current through the protection diodes at each pin. This can be extremely important in applications where the V_{BATT} pin is grounded and V_{CC} is switched on, off and on again in a short period. As V_{CC} falls, capacitance in the µP system can hold voltages at V_{OUT}, PFI or WDI up at +5V, pouring many milliamps of current through the pin protection diodes. Other manufacturer's supervisory parts may latch up in this circumstance. Once latched up, if V_{CC} is not given a chance to fall all the way to ground before the power is applied again, the part will be "stuck" and the µP system will be held in reset until the next complete power down.

The MAX691A and MAX693A have an open drain RESET output which simplifies interfacing to µP's with active high reset inputs. The RESET input on any µP will have a protection diode to V_{CC}. When V_{CC} falls to ground this diode provides a current path through the µP RESET pin to ground. Since the MAX691A and MAX693A never source current from the RESET output, the backup battery will not be discharged when V_{CC} falls. Note that the pull-up resistor is connected to V_{CC}, NOT to V_{OUT}.

SIMPLE SUPERCAP™ BACKUP CIRCUIT

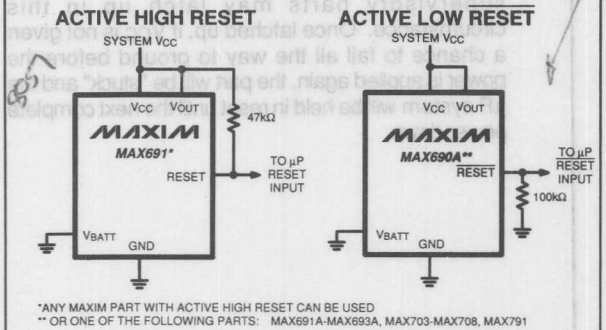


*OR ONE OF THE FOLLOWING PARTS: MAX691A-MAX693A, MAX703, MAX704, MAX791

MAXIM

High value capacitors can supplant lithium or NiCd batteries in applications requiring relatively short backup times. With microamp level backup load currents, a 0.47 Farad "SuperCap™" can keep static RAM memory backed up for several days. The 1N4148 will charge the capacitor up to VCC-0.6V very quickly, and its leakage current will charge the capacitor up to VCC in a few hours. This is OK since the MAX690A will not trigger a RESET pulse if VBATT exceeds VCC.

RESET VALID TO VCC = 0V WITHOUT BATTERY



*ANY MAXIM PART WITH ACTIVE HIGH RESET CAN BE USED
** OR ONE OF THE FOLLOWING PARTS: MAX691A-MAX693A, MAX703-MAX708, MAX791

MAXIM

Without enough gate drive, CMOS outputs lose their ability to sink and source current. An open drain output with an external pull-up resistor will rise to VCC when the supply voltage falls so low that the output loses the ability to sink current. This is fine for active high RESET inputs (because RESET becomes asserted as the power fails), but is unacceptable for active low $\overline{\text{RESET}}$ inputs (as they would be de-asserted as the power fails).

Some µP's require that $\overline{\text{RESET}}$ stay asserted down to VCC = 0.8V. MAXIM's newest supervisory parts have $\overline{\text{RESET}}$ outputs which actively source current as well as sink, so they do not need pull-up resistors and they can tolerate pull-down resistors. If a pull-down resistor is attached, the $\overline{\text{RESET}}$ line pulls to ground even when the supervisory IC cannot sink current because its supply has failed.

In battery backed up supervisory IC's, the gate drive on the internal MOS devices is the higher of VCC or VBATT. The battery voltage is sufficient to provide gate drive to the reset output devices, so $\overline{\text{RESET}}$ will always remain valid with VCC down to zero.

LOW COST SUPERVISORY ICs INCLUDE MANUAL RESET INPUTS

MAX703 — MAX708
- **Active Low RESET**
- **Manual Reset Input**
- **Power Fail Comparator**

MAX703 AND MAX704
- **5Ω Battery Backup Switch**

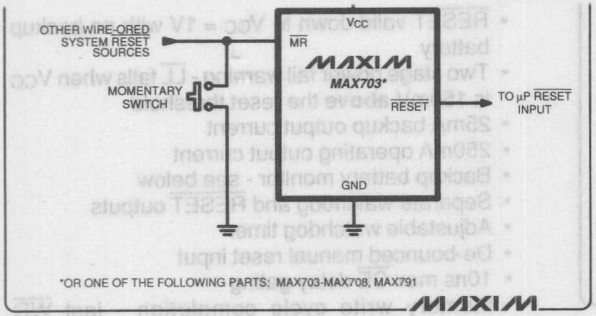
MAX705 AND MAX706
- **Separate Watchdog and Reset Outputs**

MAX707 AND MAX708
- **Active High RESET**

MAX703/705/707
- **4.65V RESET Threshold**

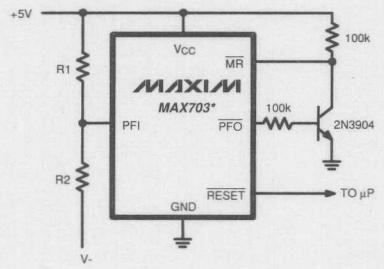
MAX704/706/708
- **4.4V RESET Threshold**

MAXIM



provides a simple de-bounced manual reset. When a user presses the switch, contact bounce will occur both at "press" and "release." The architecture of the reset circuitry ensures that the reset output becomes asserted the first time MR bounces to ground, and remains asserted without interruption until 200ms after the last rising edge of contact bounce as the switch is released.

MONITORING NEGATIVE VOLTAGES



$$\frac{5 - 1.25}{R1} = \frac{1.25 - V_{TRIP}}{R2}, \; V_{TRIP} < 0$$

*MAX704-708 CAN BE SUBSTITUTED

MAXIM

The power fail comparator of any MAXIM supervisory part can be used to monitor a negative supply rail. When the negative rail is good (a negative voltage of large magnitude), PFO is low. When the negative rail is degraded (a negative voltage of lesser magnitude), PFO goes high. The V_{TRIP} threshold accuracy is affected by the PFI threshold, resistor tolerance and the V_{CC} line variation. Note that the circuit in the diagram has no pull-up to V_{CC} on RESET: this works with the more modern parts e.g. the MAX703 to MAX708 and the MAX690A-MAX693A, but a pull-up resistor would be necessary with older parts such as the MAX690.

It may be particularly useful in telecom applications to generate a RESET pulse when the phone line voltage degrades. The MAX703 to MAX708 series of parts can be configured to reset when PFO goes high by adding an NPN transistor to perform signal inversion. As long as the negative voltage is invalid (magnitude too small), MR will be held low and the RESET line will remain asserted.

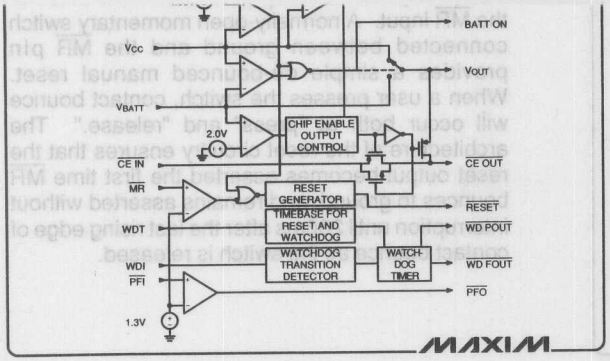
If V- goes very negative, the PFI pin may be pulled below ground. Make sure that R2 is large enough so that the internal protection diode which clamps PFI to -0.6V does not conduct more than a milliamp or so under fault conditions.

3 VOLT SUPERVISORY PRODUCTS

MAX706/708 LOW VOLTAGE VERSIONS			
	RESET THRESHOLD		
PART NUMBER	MIN	TYP	MAX
MAX706R/708R	3.00V	3.08V	3.15V
MAX706S/708S	2.85V	2.93V	3.00V
MAX706T/708T	2.55V	2.63V	2.70V

MAXIM

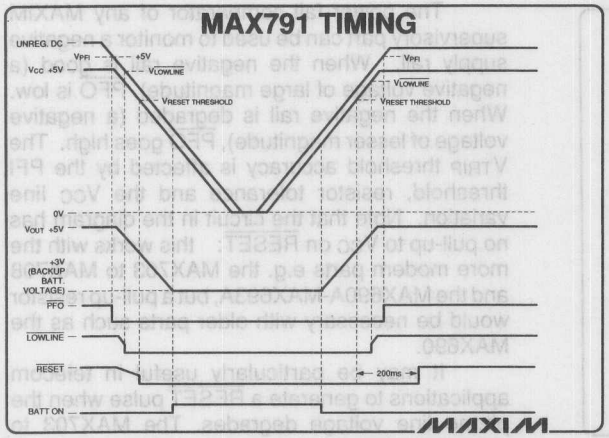
The three volt versions of the MAX706 and MAX708 have all the features of their parent parts, but are specified for 3V rather than 5V operation. They also provide guaranteed specifications at V_{CC} = 4.5V to 5.5V for mixed 3V/5V systems.

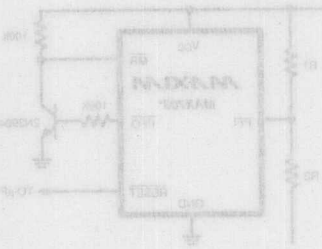


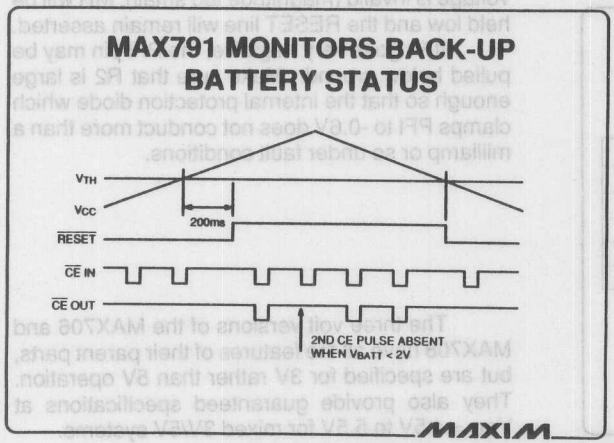
contains features not found in any other single-chip solution:

- RESET valid down to V_{CC} = 1V with no backup battery
- Two stage power fail warning - LL falls when V_{CC} is 150mV **above** the reset threshold
- 25mA backup output current
- 250mA operating output current
- Backup battery monitor - see below
- Separate watchdog and RESET outputs
- Adjustable watchdog timer
- De-bounced manual reset input
- 10ns max CE delay gating
- Memory write cycle completion - last WR completes before CE is gated out
- Additional voltage monitor - PFI and PFO

The MAX791 is not pin and functionally compatible with the MAX691 (but it's close).

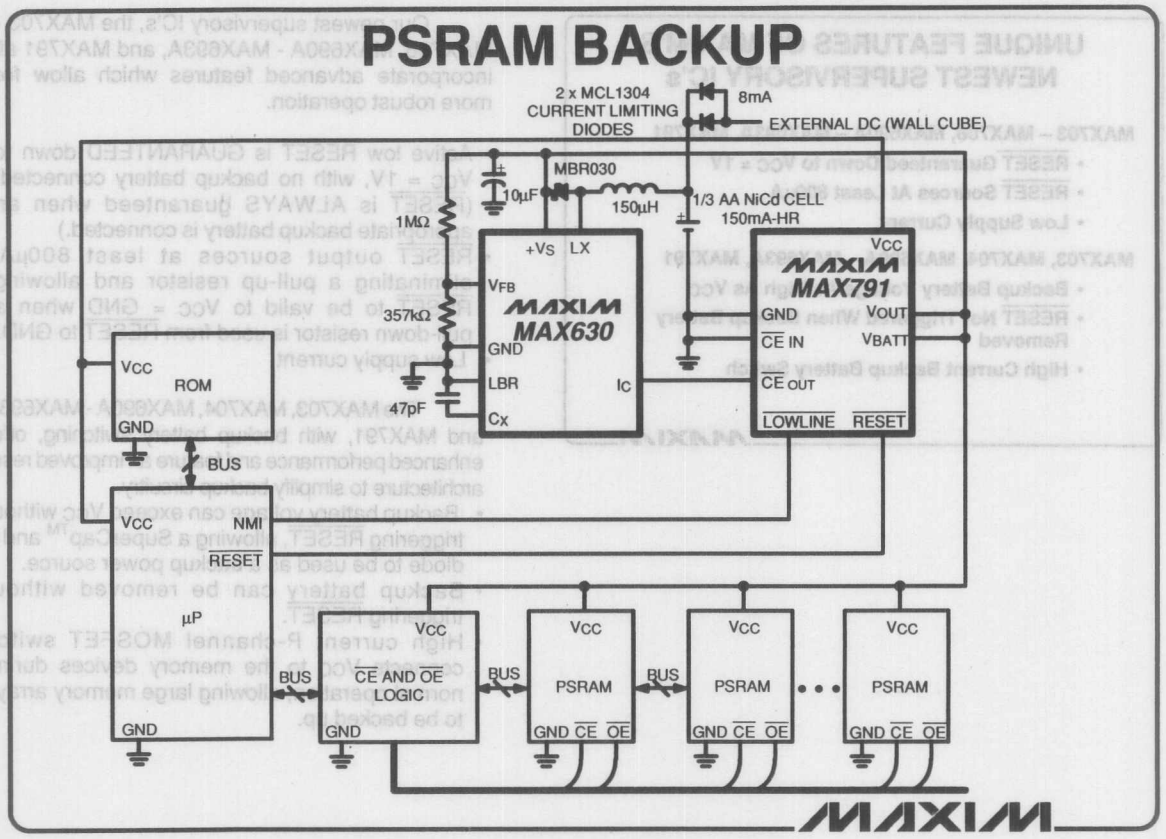






In addition to monitoring all aspects of the input supply, the MAX791 also keeps tabs on the backup battery: each time a reset pulse ends, the battery voltage is checked. If it is less than 2V, the second memory write operation is inhibited by the CE gate. Detect this immediately after reset has ended by using the first CE pulse to write value "x" to a memory location, and the second CE pulse to write value "y" to the same location. The contents of this memory location will disclose whether the second write was inhibited, and whether the backup battery was discharged.

PSRAM BACKUP



Low cost +5V Pseudo Static RAMs (PSRAMs) are dynamic RAMs with some built in refresh circuitry. They can be maintained in a low power standby state but require Vcc voltages of at least 4.0V - some even need Vcc to be greater than 4.5V. Also, unlike SRAMs (which consume as little as 2µA per chip in standby) PSRAMs consume about 100µA per chip in standby. Even though most of the refresh circuitry is built into the PSRAM, either an external clock must be supplied, or the PSRAM must be put into self-refresh mode. The circuitry to generate the clock or to force the SRAM into self refresh mode must be powered during standby as well. This further increases the standby current requirement.

A MAX791, a MAX630 and a 1/3A NiCd cell form a backup circuit that supplies the necessary +5V at milliamp current levels required by PSRAMs in case the main batteries are removed. It is also possible to back up DRAMs with this same circuit. Trickle charging the NiCd cell from the external DC source allows lower system operating current. The MAX630 offers extremely low supply current (10nA) when shutdown and very low operating current (70µA), while the MAX791 possesses unique features which allow a circuit of this type to be constructed:

- $\overline{\text{LOWLINE}}$ triggers before $\overline{\text{RESET}}$ giving the µP time to set the PSRAMs up to self refresh.
- 0.5Ω switch in the MAX791 can support the high operating current requirements of PSRAMs, allowing large memory arrays.
- Super low 70µA supply current of the MAX791 minimizes memory maintenance load when the main backup bus is in standby state, i.e. main battery not removed but the system is in a low power mode.

UNIQUE FEATURES OF MAXIM'S NEWEST SUPERVISORY IC's

MAX703 – MAX708, MAX690A – MAX693A, MAX791

- **$\overline{\text{RESET}}$ Guaranteed Down to V_{CC} = 1V**
- **$\overline{\text{RESET}}$ Sources At Least 800µA**
- **Low Supply Current**

MAX703, MAX704, MAX690A – MAX693A, MAX791

- **Backup Battery Voltage As High As V_{CC}**
- **$\overline{\text{RESET}}$ Not Triggered When Backup Battery Removed**
- **High Current Backup Battery Switch**

MAXIM

Our newest supervisory IC's, the MAX703 - MAX708, MAX690A - MAX693A, and MAX791 all incorporate advanced features which allow for more robust operation.

- Active low $\overline{\text{RESET}}$ is GUARANTEED down to V_{CC} = 1V, with no backup battery connected. ($\overline{\text{RESET}}$ is ALWAYS guaranteed when an appropriate backup battery is connected.)
- $\overline{\text{RESET}}$ output sources at least 800µA, eliminating a pull-up resistor and allowing $\overline{\text{RESET}}$ to be valid to V_{CC} = GND when a pull-down resistor is used from $\overline{\text{RESET}}$ to GND.
- Low supply current.

The MAX703, MAX704, MAX690A - MAX693A and MAX791, with backup battery switching, offer enhanced performance and feature an improved reset architecture to simplify backup circuitry.

- Backup battery voltage can exceed V_{CC} without triggering $\overline{\text{RESET}}$, allowing a SuperCap™ and a diode to be used as a backup power source.
- Backup battery can be removed without triggering $\overline{\text{RESET}}$.
- High current P-channel MOSFET switch connects V_{CC} to the memory devices during normal operation, allowing large memory arrays to be backed up.

NEW MAXIM SUPERVISORY PRODUCTS

IMPROVED ORIGINAL 690 LINE	LOW COST	HIGH PERFORMANCE	3 VOLT THRESHOLDS
MAX690A	MAX703	MAX791	MAX706R
MAX691A	MAX704		MAX706S
MAX692A	MAX705		MAX706T
MAX693A	MAX706		MAX708R
	MAX707		MAX708S
	MAX708		MAX708T

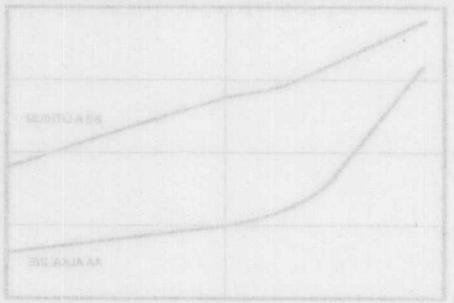
MAXIM

Even as we speak, devices are in development, and Maxim's list of supervisory circuits keeps on growing. Check to see if your requirements have been met!

POWER APPLICATIONS

- CURRENT BATTERY TECHNOLOGIES
- SINGLE CELL TO 60V, μA TO 5A SUPPLY SOLUTIONS
- BATTERY CHARGER ICs
- REGULATED CHARGE PUMPS
- 3V OUTPUT SUPPLIES
- PORTABLE POWER MANAGEMENT

MAXIM



BATTERY TYPE . . . IS DETERMINED BY MARKETING

- **Battery life target: W-hrs in = W-hrs out / Efficiency**
  Primary: more hours per use
  Secondary: reusable, provides instantaneous power
- **Size/weight: Lithium has highest energy density**
- **Cost**
- **Availability: AA or 9V PP3 easiest**
- **Form factor (shape)**
- **Self-leakage: Lithium best for long shelf life**
- **Number of charge/discharge cycles**
- **Environmental issues**

MAXIM

When designing battery-powered systems, many engineers are forced to don a Marketing hat and make critical tradeoffs in the choice of batteries and DC-DC converters. Often, even such basic issues as the decision between rechargeable (secondary) and non-rechargeable (primary) cells is left to the engineers down in the trenches.

PRIMARY BATTERY CHARACTERSITICS

	V/Cell	Energy Density (Whr/L)	Output Impedance (Ω)	Self Leakage (%/mo.)	Cost ($/Whr)
Alkaline - D -AA -9V	1.5-0.8	317 341 189	0.2 0.4 3.0	2	0.15 0.33 0.77
Carbon-Zinc-AA	1.5-0.8	150	2	5	0.42*
Lithium MnO2	3.0-1.8	450	0.3	0.2	1.25
Lithium Thionyl Chloride	3.6	440	0.3	0.2	1.50
Mercury	1.35-0.9	450	4**	0.5	2.50
Silver Oxide	1.5-0.9	400	0.6	2	3.00

* Carbon Zinc $/Whr derived with lighter load (100Ω) than used for AA Alkaline (10Ω).
** Mercury cell impedance is 4Ω for button cells, and 0.5 for AA size cylindrical cells.

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Alkaline dry cells have about a 2:1 advantage in energy density over standard carbon-zinc Leclanche cells when operated at very low discharge rates (1mA), and have about a 6:1 advantage at higher loads (100mA).

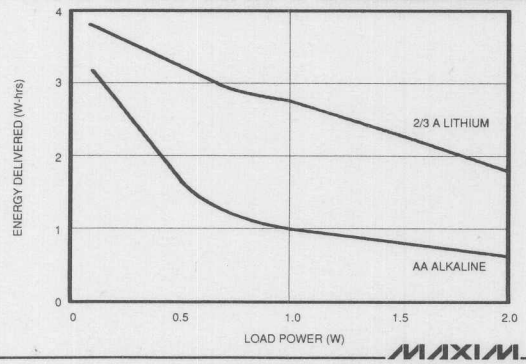
Lithium Manganese Dioxide ($LiMnO_2$) cells are generally packaged in the small coin-type batteries, and are valued in memory back-up applications because of their long shelf life. Larger, higher-power $LiMnO_2$ batteries, such as 2/3A-size, are gaining acceptance in high-end consumer applications.

Lithium Thionyl Chloride ($LiSOCl_2$) cells are noted for high energy density, and are replacing the older lithium sulfur dioxide type in military applications.

Mercury cells have good voltage stability, and maintain an approximate 1.35V output for most of their operating life.

Silver Oxide cells are the small, flat button or coin type cells used in watches and cameras, and have a flatter discharge characteristic but higher self-leakage than lithium manganese dioxide.

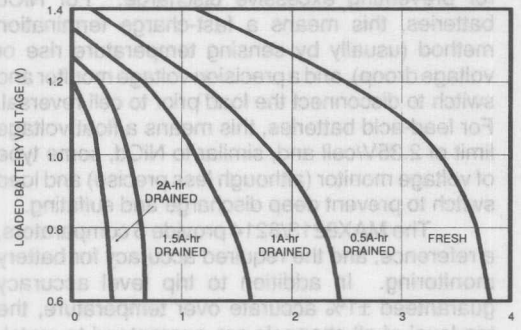
ENERGY vs. CONSTANT-POWER LOAD FOR ALKALINE AND LITHIUM



MAXIM

The total amount of energy obtained from a particular primary cell is a strong function of the rate at which current is drawn. A lightly-loaded battery will typically deliver nearly three times more watt-hours than a heavily-loaded battery. The lesson: doubling the physical size of the battery can sometimes triple the system battery life (and not just because the battery casings are taking up less space).

INSTANTANEOUS POWER vs. BATTERY VOLTAGE FOR ONE ALKALINE AA



MAXIM

As a battery is discharged, its internal impedance increases. This means that a half-dead battery may be unable to supply the peak power demands from the system, even though the battery still has watt-hours of life left in it. For example, motor spin-up currents or flash EEPROM programming currents may hit the battery so hard that the main power supply voltage collapses, disrupting the system. Alkaline and lithium batteries are particularly prone to this phenomenon of increasing resistance with discharge. Some of the small coin cells can degrade to 1000Ω or more. One possible solution is to use a small NiCd battery as a capacitor to handle surges.

SECONDARY BATTERY CHARACTERSITICS

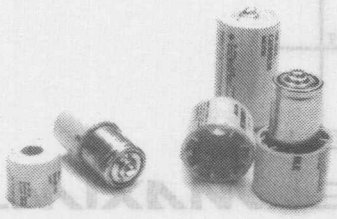
	V/Cell	Energy Density (Whr/L)	Output Impedance (Ω)	Charge Cycles	Self Leakage (%/mo.)	Cost ($/Whr)
NiCd	1.35-1.0	120	0.02	800	25	3.75
NiMH	1.4-1.1	174	0.02	500	30	2.50
Lead-Acid	2.4-1.6	100	0.01	300	6	1.30
Lithium-Ion	3.6	230	0.05	1000	0.3	N/A

MAXIM

New rechargeable battery chemistries that provide higher energy density than standard Nickel-Cadmium (NiCd) or lead-acid gel cells are emerging. Nickel-metal hydride (NMH) is here today, and provides similar characteristics to NiCd and has 50% higher energy density. Lithium ion types, such as those made by Sony Energytec and Asahi are just coming out now, and provide twice the energy density of NiCd.

Most secondary batteries have extremely low internal impedance; for example, a lead acid D cell can deliver up to 100A for short periods.

REPACKAGED SUB-C BATTERIES COMPRISE C- AND D-SIZE CELLS



MAXIM

Consumer C- and D-size NiCd batteries are usually repackaged sub-C batteries.

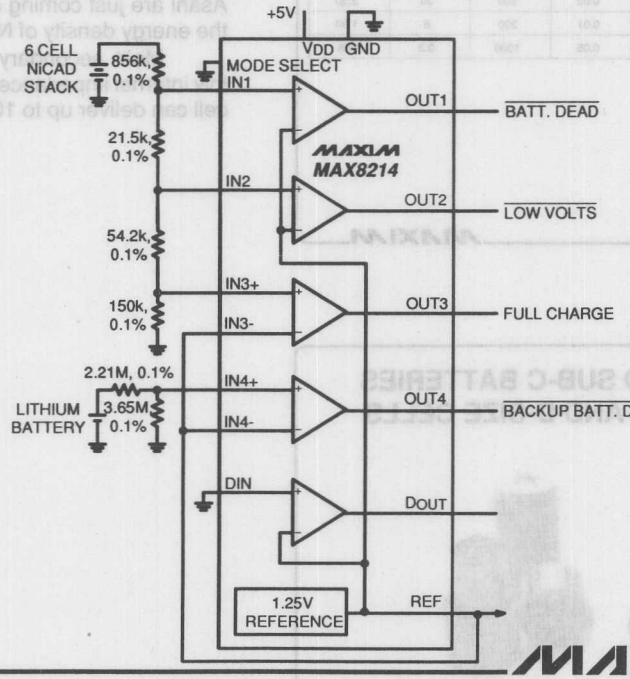
- **1% Trip Levels Guaranteed Over Temp.**
- **30µA Supply Current**
- **Built-In Hysteresis**
- **Slow Comparator Response for Glitch Immunity**
- **Undervoltage, Overvoltage, and Window Comparison of Positive and Negative Voltages**
- **1.25V Reference**

MAXIM

method (usually by sensing temperature rise or voltage droop), and a precision voltage monitor and switch to disconnect the load prior to cell reversal. For lead-acid batteries, this means a float voltage limit of 2.35V/cell and, similar to NiCd, some type of voltage monitor (although less precise) and load switch to prevent deep discharge and sulfating.

The MAX8213/8214 provide 5 comparators, a reference, and the required accuracy for battery monitoring. In addition to trip level accuracy guaranteed ±1% accurate over temperature, the trip level of all channels are guaranteed to match each other with 1%. The comparator response time is 5 to 10µs, purposefully slowed to minimize glitches at the comparator outputs. The MAX8213 has open-drain outputs, whereas the MAX8214 outputs have active pullups.

MAX8214 MONITORS BATTERY LEVELS DURING CHARGE AND DISCHARGE



MAXIM

Resistor ratios for monitoring the NiCd battery are chosen to detect when the battery (1) has charged to 1.5V/Cell, (2) has discharged to 1.1V/Cell, and (3) has completely discharged to 1.0V/Cell. The Lithium backup battery is considered dead when its voltage equals 2.0V.

Note that when the monitored voltage is falling, the comparator trip point is equal to the reference voltage (1.25V); however, when the voltage is rising, the trip point is equal to the reference plus about 15mV hysteresis.

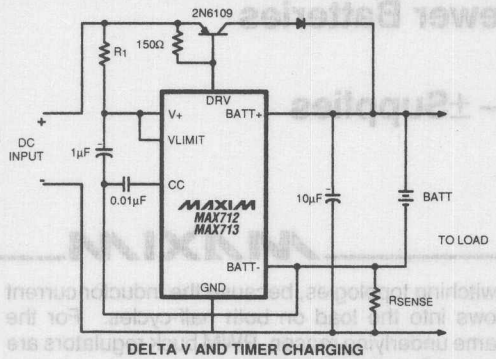
- Charge 1-16 series cells, MAX713 for NiCd, MAX712 for NiMH
- **Fast charge at from C/4 to 4C rates**
- **Delta V, timer, voltage ceiling and/or temperature window charge limit**
- **+5V shunt regulator powers IC and light loads from the external DC power source**
- **Draws 5µA MAX from Battery when not charging**
- **Regulates battery current in presence of external load**

MAXIM

batteries are fully charged, while the MAX712 detects zero voltage slope for NiMH batteries. These devices integrate all the necessary fast-charging circuitry into a 16-pin SO package.

Fast charge timeout can be set between 22 and 264 minutes. The built-in voltage reference and window comparator are used to terminate fast charging when the battery temperature lies outside a user-selectable window. When fast charge ends, trickle charging continues at a C/16 rate. The active-low fast charge status indicator directly drives an LED. External components are limited to an external PNP, a diode, a few resistors and capacitors, and two thermistors if optional temperature sensing is used.

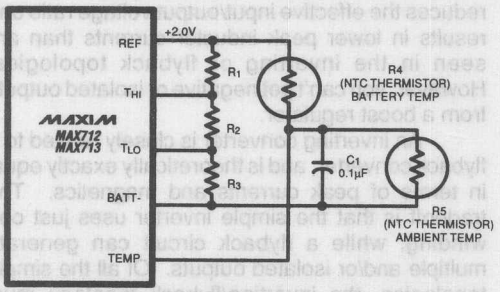
FAST CHARGE NiCd & NiMH BATTERIES



DELTA V AND TIMER CHARGING

MAXIM

FAST CHARGE NiCd AND NiMH BATTERIES



OPTIONAL TEMPERATURE SENSING CHARGE LIMIT

MAXIM

BATTERY-POWER DC-DC TOPOLOGIES

- **No Regulator – Lowest Cost**
- **Linear Reg – Low Noise**
- **Charge Pumps – No Inductors**
- **Buck DC-DC Regulator – Low I_{PEAK}**
- **Boost Regulator – Fewer Batteries**
- **Inverting Regulator – ±Supplies**

MAXIM

After settling basic battery and charger issues, the next step in designing a battery-powered system is selecting the DC-DC converter topology.

If at all possible, design the system to operate directly from the naked battery. Failing that, a linear regulator requires no magnetics, is small and cheap, and generates no EMI. However, linear regulators cannot step up a low battery voltage, and become inefficient with large input-output voltage differentials.

The first choice in switch-mode converters is a charge pump, which relies on capacitors rather than inductors for energy storage. Charge pumps are almost as small and cheap as linear regulators, and can step-up and invert the input voltage. However, charge pump ICs generally have limited output power capability (0.5W or less) due to the number of switch IR drops, and are not well-suited for fractional output voltages or wide input/output voltage ratios.

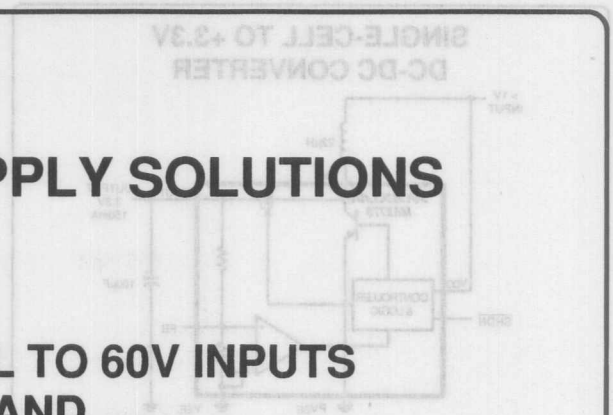
If magnetics become necessary, a buck regulator is the first choice. The peak currents required in a buck regulator are lower than in other switching topologies, because the inductor current flows into the load on both half-cycles. For the same underlying reason, PWM buck regulators are more AC stable than boost regulators and lack a right-half-plane zero present in the feedback loop of boost regulators. But buck regulators can only step down the input voltage.

A boost (step-up) regulator is the next most desirable, mainly because the battery voltage aids the series inductor discharge voltage. This aiding reduces the effective input/output voltage ratio and results in lower peak inductor currents than are seen in the inverting or flyback topologies. However, you can't get negative or isolated outputs from a boost regulator.

An inverting converter is closely related to a flyback converter, and is theoretically exactly equal in terms of peak currents and magnetics. The tradeoff is that the simple inverter uses just one winding, while a flyback circuit can generate multiple and/or isolated outputs. Of all the simple topologies, the inverting/flyback topology must bear the highest peak currents for a given load.

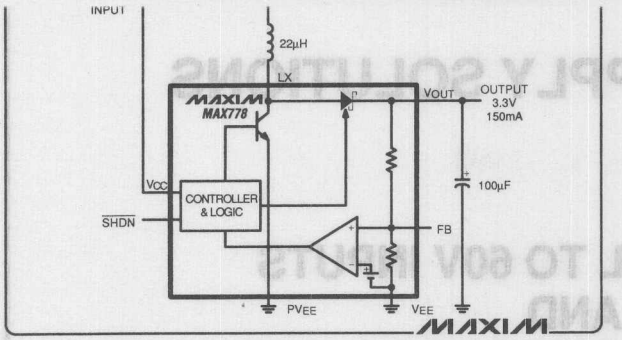
SPECIFIC SUPPLY SOLUTIONS

SINGLE CELL TO 60V INPUTS AND MICROAMP TO 5A OUTPUTS



MAXIM

The following slides show solutions to various supply scenarios. Designs with single cell to 60V inputs and microamp to 5A outputs are covered. Material is covered in order from lower to higher input voltages.



bipolar switching transistor is a good alternative to MOSFETs, especially to discrete power MOSFETs, the best of which have a very high 2V maximum threshold voltage spec.

The MAX777/778/779 are micropower DC-DC step-up converters. They accept 1V to 5V (1-cell to 3-cell) inputs and deliver fixed 3V, 3.3V, 5V, or adjustable outputs. They require only two external components: typically a 22µH inductor and a 100µF capacitor. Each contains a 1A power switch and delivers output currents over 380mA. Efficiency is typically 70% to 90%. They use an internal active rectifier which completely turns off in shutdown mode, disconnecting the load from the source and reducing quiescent supply current to 30µA.

MAX777 FAMILY OF 1V TO 5V INPUT PFM REGULATORS

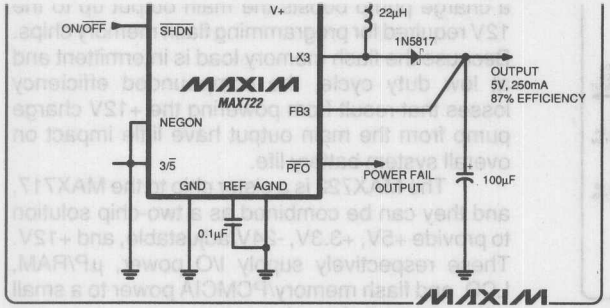
FEATURES	ADVANTAGES
1V Start-Up Input Voltages	Fewer Cells
Only 2 External Components	Speeds Design Cycles
Small External Components	Saves Space
Internal Active Rectifier	Complete Disconnect of Load From Supply
20µA Shutdown Mode	Saves Battery Life

MAXIM

MAX777 FAMILY OF 1V TO 5V INPUT PFM REGULATORS

	V_{OUT}	V_{IN}	I_Q	I_{OUT}
MAX777	+5V	1V TO 5V	220µA	UP TO 225mA
MAX778	+3V/+3.3V	1V TO 5V	220µA	UP TO 380mA
MAX789	ADJ. (3V TO 6V)	1V TO 5V	220µA	UP TO 380mA

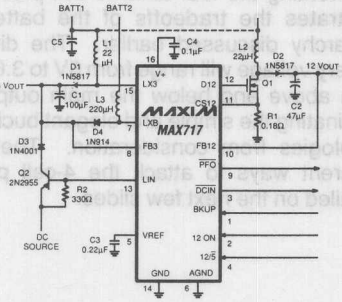
MAXIM



is typically 87%. The MAX722 draws only 20µA when shut down under digital control.

This tiny regulator comes in a narrow 14-pin SOIC which includes the power switch. External components are kept small thanks to a 500kHz switching frequency. The 250mA output application requires only a 22µH inductor, a 100µF capacitor, a diode, and a 0.1µF bypass capacitor. There is even a power fail output pin for monitoring the output voltage and signaling the microprocessor when the output falls out of regulation.

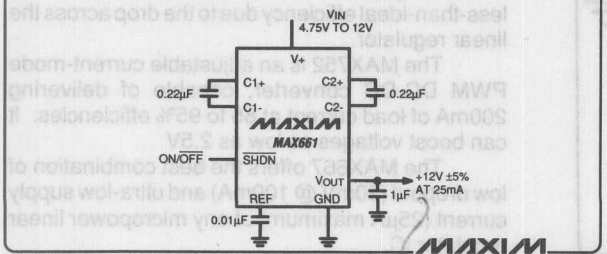
PALMTOP COMPUTER 2-CELL/3-CELL DC-DC



When two or three series cells power a small but sophisticated microprocessor-based system such as a palmtop computer or digital camera, the power levels generally preclude charge pump solutions. For these applications, the MAX717 provides an inductor-based solution. The MAX717 generates dual regulated outputs from one of three input voltage sources: an AC-DC wall-cube adaptor (7V to 20V), a main 2- or 3-cell battery, or a lithium backup battery. Miniature (5mm diameter) inductors are made possible by a relatively high 0.5MHz maximum switching frequency. While one might expect to pay the penalty of increased supply current for 0.5MHz operation, the MAX717 draws only 60µA, due to an advanced pulse-skipping PFM control scheme (more on this later).

MAX661 +12V FLASH MEMORY PROGRAMMING SUPPLY

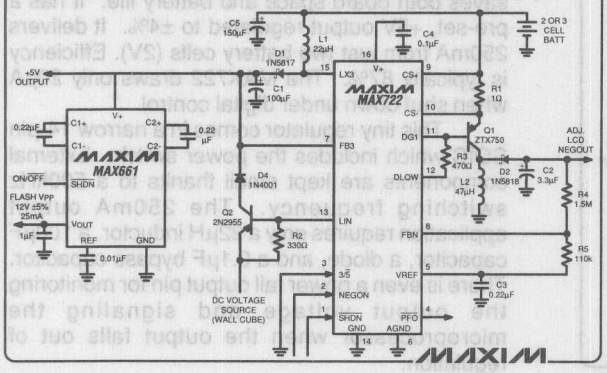
- **5V Input/12V Output Regulated Charge Pump**
- **No Inductors—Ultra Small**
- **50µA Supply Current**
- **<1µA Shutdown Current**
- **All Capacitors ≤1µF**



The MAX661 is a regulating charge pump specifically designed for programming flash memory. The MAX661 solution is quite small, requiring only tiny ceramic chip capacitors, and drawing only 50µA of quiescent supply current (<1µA in shutdown mode). Efficiency is reasonably good for a regulated charge pump, exceeding 70% over almost the entire load range.

(Intel "requires" 30mA but tests have shown 25mA are fine.)

PALMTOP COMPUTER DC-DC WITH ADJUSTABLE LCD AND FLASH VPP



Often, a combination of inductor-based switch-mode regulators and charge pumps proves to be the best overall solution. In this case, an inductor-based DC-DC provides the main output power and a negative LCD contrast control, while a charge pump boosts the main output up to the 12V required for programming flash memory chips. Because the flash memory load is intermittent and at low duty cycle, the compounded efficiency losses that result from powering the +12V charge pump from the main output have little impact on overall system battery life.

The MAX722 is a sister chip to the MAX717, and they can be combined as a two-chip solution to provide +5V, +3.3V, -24V/adjustable, and +12V. These respectively supply I/O power, µP/RAM, LCD, and flash memory/PCMCIA power to a small microprocessor-based system.

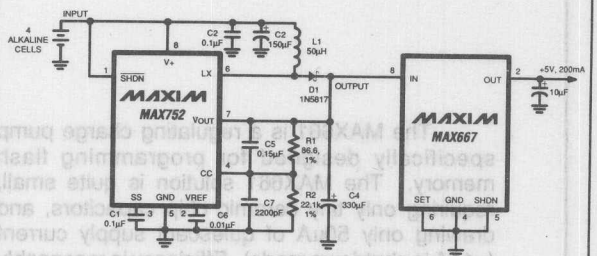
CONVERTING 4 CELLS TO 5 VOLTS

- **Boost DC-DC followed by linear regulator**
- **Invert the output and float the battery**
- **Straight flyback transformer**
- **Buck-boost with flying inductor**
- **Change numbers of cells**

MAXIM

Generating +5V from four series alkaline or zinc batteries is a special case that places tough requirements on the main DC-DC converter. Confronting the four-alkaline-cell problem clearly illustrates the tradeoffs of the battery DC-DC hierarchy discussed earlier. The difficulty: the battery voltage will range from 6V to 3.6V, which is both above and below the main output voltage, eliminating the simple and elegant buck and boost topologies from consideration. There are five different ways to attack the 4-cell problem, all detailed on the next few slides.

FOUR ALKALINE CELLS TO +5V: BOOST PLUS LINEAR REGULATOR

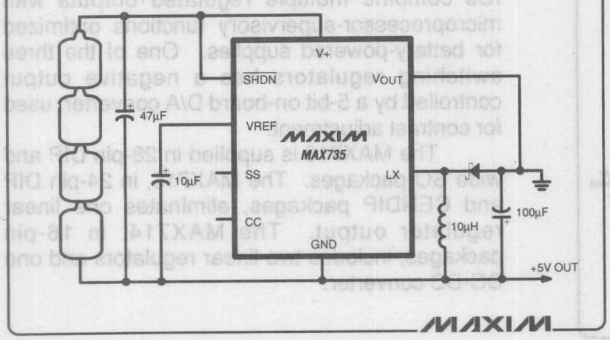


In four-cell applications, the simple boost topology allows the output to follow the input (minus a diode drop), resulting in high output voltages that might damage sensitive loads. One obvious solution: follow the boost regulator output with a linear regulator. This works, but delivers less-than-ideal efficiency due to the drop across the linear regulator.

The MAX752 is an adjustable current-mode PWM DC-DC converter, capable of delivering 200mA of load current at 85 to 95% efficiencies. It can boost voltages as low as 2.5V

The MAX667 offers the best combination of low dropout (90mV @ 100mA) and ultra-low supply current (25µA maximum) of any micropower linear regulator IC.

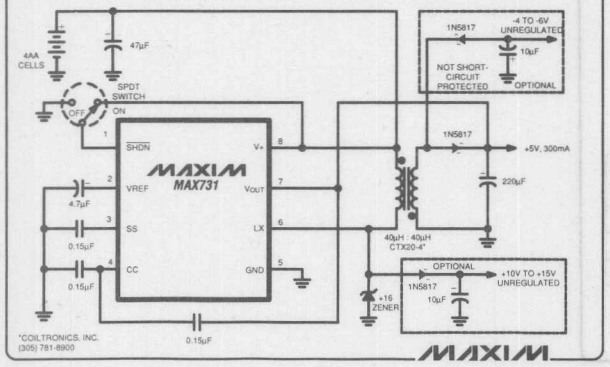
4 ALKALINE CELLS TO +5V: INVERTER PLUS FLOATING BATTERY



Another tactic to apply to the 4-cell problem is inverting the battery voltage and moving the ground reference to the negative output. The tradeoff here is a floating battery: the minus side is connected to the +5V output. This may be a problem if other loads in the circuit are referenced to the battery "ground" or if additional voltages must be generated from the stack of batteries. Also, the ratio of peak switch current to load current in this circuit is relatively high (about three times that of a buck regulator with the same output power), necessitating a relatively big inductor core. Also, high peak currents mean high I^2R losses and somewhat poorer efficiency.

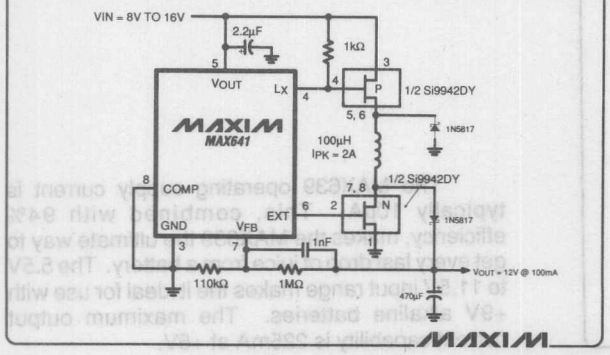
The MAX735 is a -5V output inverting current-mode PWM regulator, capable of supplying a 200mA output current when driven by a 4.5V or higher input voltage. Input voltages as low as 4V are allowed. The part includes a 10µA shutdown mode, undervoltage lockout, and soft-start.

4 AA CELLS TO +5V: FLYBACK TRANSFORMER APPROACH



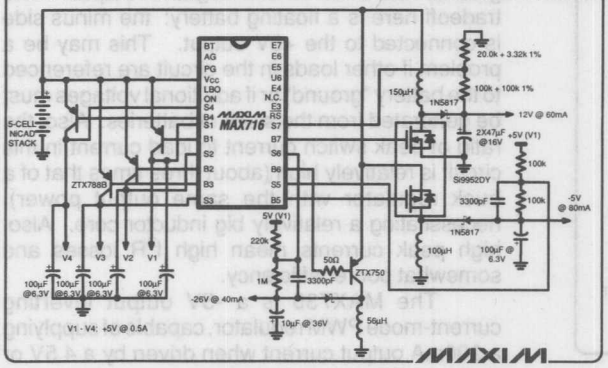
Another solution to the 4-cell problem is the time-honored flyback transformer approach. Since the output is not coupled to the input (but not isolated in this case), the input can vary above and below the regulated output. The tradeoff: you can get loosely-regulated multiple outputs, but the peak currents are no lower than those in a simple inverter. Also, the transformer always will be a little bigger and more expensive than the inductor required in an inverting or boost topology.

4 CELLS TO +5V: BUCK-BOOST WITH FLYING INDUCTOR



This circuit is introduced more as a laboratory curiosity than as a serious contender against the evil four-cell battery pack. It combines the worst features of a charge pump solution (multiple switch drops) with the worst features of an inverter (high peak-current to load-current ratio). In spite of these drawbacks it can still be useful, especially if you despise transformers and must have a grounded battery.

FIVE NiCd/NiMH CELLS: SYSTEM SOLUTION WITH LINEAR AND SWITCHING REGULATORS



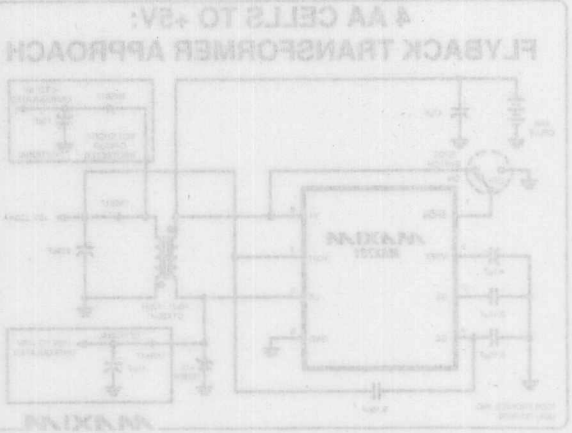
The MAX714/715/716 are highly integrated energy management ICs for 5-cell and 6-cell battery-operated microprocessor systems. These ICs combine multiple regulated outputs with microprocessor-supervisory functions optimized for battery-powered supplies. One of the three switching regulators has a negative output controlled by a 5-bit on-board D/A converter, used for contrast adjustment.

The MAX716 is supplied in 28-pin DIP and wide SO packages. The MAX715, in 24-pin DIP and CERDIP packages, eliminates one linear regulator output. The MAX714, in 16-pin packages, includes two linear regulators and one DC-DC converter.

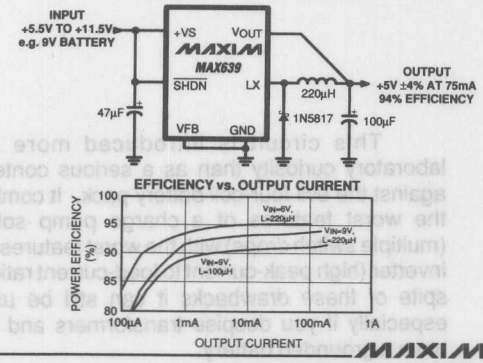
MAX714 - MAX716 FAMILY

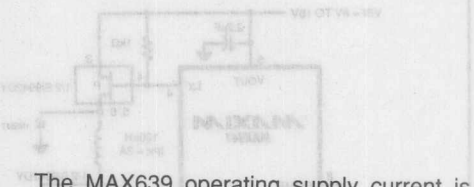
- Fully Independent Digitally Controlled Outputs
- 35µA Standby Quiescent Current
- 100mV Linear Regulator Dropout
- Microprocessor Reset Output

	# of +5V Linear Regulators	+12V Stepup	-5V Inverting	DAC-Controlled LCD Driver	Low Battery Detector	Automatic Battery Backup
MAX714	2			✔	✔	✔
MAX715	3	✔	✔	✔	✔	✔
MAX716	4	✔	✔	✔	✔	✔



THE ULTIMATE WAY TO SQUEEZE A 9V BATTERY DRY





The MAX639 operating supply current is typically 10µA. This, combined with 94% efficiency, makes the MAX639 the ultimate way to get every last drop of juice from a battery. The 5.5V to 11.5V input range makes the it ideal for use with +9V alkaline batteries. The maximum output current capability is 225mA at +5V.

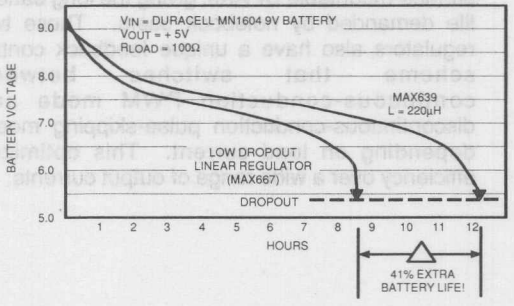
LINEAR REGULATORS vs. DC-DC CONVERTERS

- **Linear Regulators Have Constant Input Current**
- **DC-DC Converters Have Constant Input Power**
- **Few DC-DC Converters Have**
  - **Wide Input Range**
  - **Low IQ**
  - **Low Dropout Voltage**
- **DC-DC Converter Eff. > 90% for 2mA < I_L < 200mA**

MAXIM

The input power of a DC-DC converter is constant, whereas a linear regulator has constant input current. Therefore, for higher input voltages, the DC-DC converter has better efficiency. Few DC-DC converters have a wide input range, low quiescent current, and a low dropout voltage, which is why linears have been a better choice for battery-input regulators up to now.

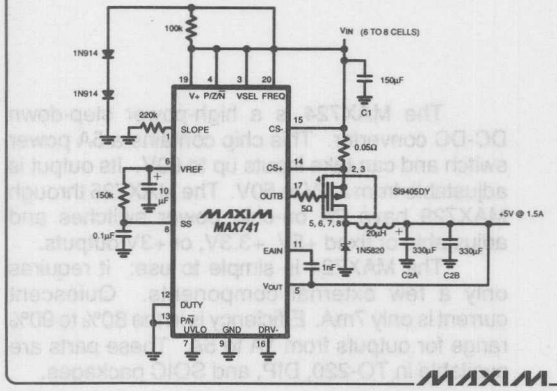
MAX639 vs. LOW DROPOUT LINEAR



MAXIM

The MAX639 conversion efficiency exceeds 90% for output currents ranging from 2mA to 200mA. With a 100Ω load it adds 41% to the life of an alkaline 9V battery.

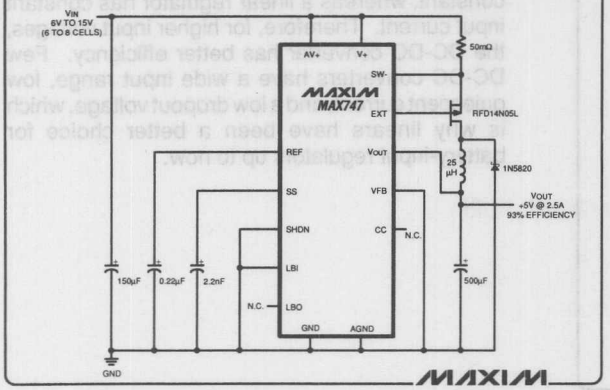
6-8 CELLS: +5V AT 1.5A



MAXIM

The MAX741 Current-Mode PWM controller provides an excellent high efficiency solution for stepping down 6-8 NiCad or Nickel Metal Hydride cells to +5V at 2A. Driving a high efficiency, low R_{ON} P-channel MOSFET, the circuit delivers +5V @1A with 92% efficiency with 6 cells, and 90.5% efficiency with 8 cells. An adjustable mode allows other output voltages (such as +3.3V or +3V) by adding external resistor feedback.

6-8 NiCd/NiMH CELLS: +5V AT 2.5A

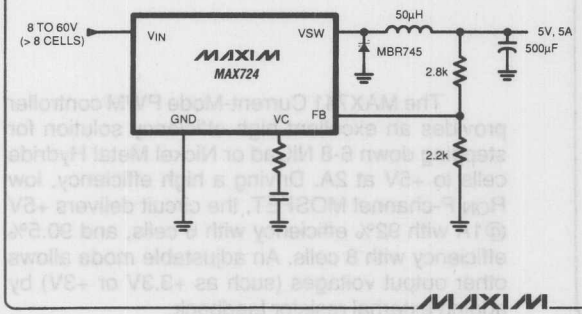


The MAX746 and MAX747 are high-efficiency, high-current step-down controllers, intended for use as the main power supply in notebook and laptop computers. They convert an input in the range of 6V to 15V (6 to 8 NiCad cells) to an output of 5V and 2.5A, guaranteed over temperature. Typical efficiency from 500mA to 2.5A is 93%. In operating mode, quiescent supply current is 1mA max. It is 20µA max in shutdown mode.

The MAX746 controls an external N-channel power switch, while the MAX747 drives an external P-channel MOSFET. Both devices come in narrow SOIC packages and require a minimum of external components. The inductor (25µH) and output capacitor (500µF) are physically small due to the 200kHz switching frequency. A 2% accurate low-battery detector is included to save board space and add convenience.

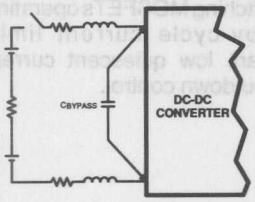
A unique feature of the MAX746 is that it drives the N-channel logic FET on the high-side. The high-side driven N-channel switch provides very low on-resistance in low-cost surface-mountable DPAKs, giving the long battery life demanded by notebook users. These two regulators also have a unique feedback control scheme that switches between continuous-conduction PWM mode and discontinuous-conduction pulse-skipping mode, depending on load current. This optimizes efficiency over a wide range of output currents.

GREATER THAN 8 NiCd/NMH CELLS: +5V AT 5A



The MAX724 is a high-power step-down DC-DC converter. This chip contains a 5A power switch and can take inputs up to 60V. Its output is adjustable from 2.5V to 50V. The MAX726 through MAX729 have 2A on-chip power switches and adjustable or fixed +5V, +3.3V, or +3V outputs.

The MAX724 is simple to use: it requires only a few external components. Quiescent current is only 7mA. Efficiency is in the 80% to 90% range for outputs from 1A to 5A. These parts are available in TO-220, DIP, and SOIC packages.



through optimum use of chemistry

- Reduces I^2R losses in battery wiring, switches, connectors
- Eliminates voltage drop due to inductance of supply cables
- Reduces radiated noise
- Reduces conducted noise
- Required for converter stability

MAXIM

peak currents cuts down losses which are proportional to the square of the current.

- It virtually eliminates voltage drop due to inductance of supply cables.
- It reduces the **conducted** noise sent back down the line. This may be unimportant if this DC-DC converter is the only thing hanging on the battery, but it can be crucial if you have other equipment taking power from the same supply.
- It reduces the noise **radiated** from the antenna formed by the wires carrying the pulsed current.
- The supply voltage for a DC-DC converter IC should remain stable, and relatively free of high frequency noise, to ensure proper operation of the reference and other circuitry. In many cases a small (0.1µF) capacitor mounted close to the IC supply pins is adequate. Larger capacitors, or large/small parallel combinations, are usually needed when the power switch is contained within the controller IC.
- If you are testing your DC-DC converter using a bench power supply as the input, note that although the DC output impedance of the supply may be close to zero its output impedance at the frequencies of interest (e.g. 50kHz or higher) may be substantial. Many circuits tested in this way simply will not work unless adequately bypassed.
- How do you choose the value and type of the bypass capacitor(s)? Low effective series resistance (ESR) capacitors give much lower ripple voltages when carrying high peaks of current. Note that capacitor ESR tends to rise at low temperatures. Higher capacitance leads to lower ripple, but beyond a certain limit the benefit of doubling capacitor size becomes very small. Parallel combinations of large/small capacitors, e.g. 0.1µF//100µF, often provide good bypassing over a wide range of frequencies. The absolute values needed will depend on the DC-DC converter and on the impedance of the incoming supply, and are best determined initially by overkill followed by experiment to find the minimum practical values.

PWM REGULATORS WITH INTERNAL POWER MOSFETs MAX730 FAMILY

FEATURE	ADVANTAGE
High-Efficiency (80% to 90%)	Longer Battery Life
High 170kHz Switching Frequency	Smaller Components, Easier Output Filtering
Low Input Supply Voltages	Fewer Cells
Logic-Controlled Shutdown	Longer Battery Life
Current-Mode PWM Control	Low Output Noise

MAXIM

For more modest power requirements (less than 2W) Maxim's current-mode PWM regulators provide extremely efficient power conversion for step-up, step-down, and inverting applications. All have on-board 1.5A switching MOSFETs operating at 170kHz, cycle-by-cycle current limit, programmable soft-start, low quiescent current (typically 2mA), and shutdown control.

MAXIM CURRENT-MODE PWM REGULATOR FAMILY

V_{OUT}	V_{IN}	TYPE	I_{OUT}/P_{OUT}	PART#	EFF%
5V	2.5V-5.5V	STEP-UP	200mA	MAX731	87%
	6.0V-11V	STEP-DOWN	300mA	MAX730	92%
	6.6V-16V	STEP-DOWN	300mA	MAX738	90%
	10.2V-16V	STEP-DOWN	750mA	MAX738	86%
12V	2.5V-9.3V	STEP-UP	60mA	MAX734	90%
	4.5V-9.3V	STEP-UP	150mA	MAX732	92%
	6V-9.3V	STEP-UP	200mA	MAX732	94%
	13V-15V	STEP-DOWN	200mA	MAX758	92%
15V	4.5V-11V	STEP-UP	100mA	MAX733	92%
ADJ. POS	V_{OUT} +.5V-11V	STEP-DOWN	TO 3W	MAX758	*
	V_{OUT} +.5V-16V	STEP-DOWN	TO 3W	MAX750	*
	2.5V-V_{OUT} +.5V	STEP-UP	TO 1W	MAX752	*
-5V	4V-6.2V	INVERT	200mA	MAX735	87%
	4V-15V	INVERT	250mA	MAX739	84%
-12V	4V-8.6V	INVERT	125mA	MAX736	82%
	4V-15V	INVERT	125mA	MAX759	82%
-15V	4V-5.5V	INVERT	100mA	MAX737	80%
	4V-15V	INVERT	100mA	MAX759	80%
ADJ. NEG	4V-15V	INVERT	TO 1W	MAX759	*

MAXIM

NEW GENERATION PULSE-SKIPPING PFM REGULATORS MAX760-6, MAX770-6, MAX639/649

FEATURE	ADVANTAGE
High-Efficiency (80% to 90%)	Saves Battery Life
Low 100µA Quiescent Supply Current	Saves Battery Life
5µA Shutdown Mode	Saves Battery Life
Fast 125kHz Switching Frequency	Smaller External Components
Unique PFM Control Scheme	Minimal External Components

MAXIM

The MAX760-6, MAX770-6, and MAX639/649 are Maxim's latest family of general purpose micropower DC-DC converters. They offer improvements to the trend-setting MAX630 and MAX640 DC-DC converter families: lower supply currents, higher efficiencies, and faster (125kHz) effective switching rates, which translate to smaller external components. These devices have also made choosing external components easier. All of these devices feature fixed/adjustable outputs.

MAX760 & MAX770 FAMILY OF MICROPOWER PFM REGULATORS

VOUT	VIN	FUNCTION	PART#
+5V	2V TO 5.2V	STEP-UP	MAX760
	2V TO 5.2V	STEP-UP CONTROLLER	MAX770
	5.2V TO 11.5V	STEP-DOWN	MAX639
	5.2V TO 16V	STEP-DOWN CONTROLLER	MAX649
+12V	2V TO 12.4V	STEP-UP	MAX761
	2V TO 12.4V	STEP-UP CONTROLLER	MAX771
	12.2V TO 16V	STEP-DOWN CONTROLLER	MAX649
+15V	2V TO 15.6V	STEP-UP	MAX762
	2V TO 15.6V	STEP-UP CONTROLLER	MAX772
+3.3V*	2V TO 3.4V	STEP-UP	MAX760
	2V TO 3.4V	STEP-UP CONTROLLER	MAX770
	4V TO 11.5V	STEP-DOWN	MAX639
	3.5V TO 16V	STEP-DOWN CONTROLLER	MAX649

MAXIM

MAX760 & MAX770 FAMILY OF MICROPOWER PFM REGULATORS (cont.)

VOUT	VIN	FUNCTION	PART#
ADJ. POS.			
UP TO 28V	2V TO 16.5V	STEP-UP	MAX760/1/2
UP TO 28V	2V TO 28V	STEP-UP CONTROLLER	MAX770/1/2
UP TO 48V	2V TO 48V	STEP-UP CONTROLLER	MAX773
DOWN TO 1.2V	4V TO 11.5V	STEP-DOWN	MAX639
DOWN TO 1.2V	2V TO 16V	STEP-DOWN CONTROLLER	MAX649
-5V	2V TO 15.6V	INVERTER	MAX764
	3V TO 16.5V	INVERTER CONTROLLER	MAX774
-12V	2V TO 8.5V	INVERTER	MAX765
	3V TO 16.5V	INVERTER CONTROLLER	MAX775
-15V	2V TO 5.4V	INVERTER	MAX766
	3V TO 16.5V	INVERTER CONTROLLER	MAX776
ADJ.NEG.			
(VIN/VOUT DIFF < 21V)	2V TO 21V	INVERTER	MAX764/5/6
(VIN/VOUT DIFF LIMITED BY EXT. SWITCH)	3V AND ABOVE	INVERTER CONTROLLER	MAX774/5/6

MAXIM

POWER SUPPLY EVALUATION KITS

Base Kits Available For:

- Step-Down DC-DC Converters
- Step-Up DC-DC Converters
- Inverting DC-DC Converters
- Dual Output (Step-Up/Inverting) DC-DC Converter
- Multiple Output Complete Supply Systems

Alternative Devices May Be Substituted in Base Kit
SO and DIP Versions Available
Some Kits With SO Devices Preassembled

MAXIM

POWER SUPPLY EVALUATION KITS

Base Kits	Also evaluates these devices (Order separate free sample along with base kit)
Step-Down DC-DC Converters	
MAX639EVKIT-DIP	
MAX639EVKIT-SO	
MAX738EVKIT-DIP	MAX730CPA
MAX738EVKIT-SO	MAX730CSA
MAX758EVKIT-DIP	MAX750CPA
MAX758EVKIT-SO	MAX750CSA
Step-Up DC-DC Converters	
MAX655EVKIT-DIP	MAX654CPD, MAX657CPD
MAX731EVKIT-DIP	MAX732CPA, MAX733CPA
MAX732EVKIT-SO	
MAX752EVKIT-DIP	
Inverting DC-DC Converters	
MAX739EVKIT-DIP	MAX736CPD, MAX737CPD, MAX759CPD
MAX759EVKIT-SO	

MAXIM

In the right column is a listing of additional similar devices which can be evaluated using the base kit. To evaluate a device that does not have its own kit, order the base kit and a free sample of the device to be evaluated. Use only the names of the base kits when ordering kits.

For example, to evaluate the MAX730 in DIP package, order the MAX738EVKIT-DIP and a separate MAX730CPA free sample. Notice there is no kit named "MAX730EVKIT-DIP."

POWER SUPPLY EVALUATION KITS

Base Kits	Also evaluates these devices (Order separate free sample along with base kit)
Dual Output (Step-Up/Inverting) DC-DC Converter	
MAX743EVKIT-DIP	
Multiple Output Complete Power Supply Systems	
MAX716EVKIT-SO	
MAX718EVKIT-SO	MAX717CSE, MAX719CSE
MAX722EVKIT-SO	MAX723CSE

Note that the following kits are completely pre-assembled with surface-mounted devices. They are targeted for specific applications.

MAX716EVKIT-SO	"Small Microprocessor-Controlled Systems Supply EVKIT"
MAX718EVKIT-SO	"Palmtop Computer & Flash Memory Power Supply EVKIT"
MAX722EVKIT-SO	"Palmtop Computer & LCD Driver Power Supply EVKIT"
MAX732EVKIT-SO	"Flash Memory Power Supply EVKIT"
MAX759EVKIT-SO	"LCD Driver EVKIT"

MAXIM

OPERATIONAL AMPLIFIERS

	Low Noise	Low Voltage	Low Power	High Speed	Precision
MAX410/412/414	✔	✔		✔	
MAX406/407		✔	VERY!		
MAX402/403/438/439			✔	✔	
MAX480		✔	✔		✔
MAX427/437	✔			✔	✔

MAXIM

- ±2.4V to ±5.5V Supply Voltage Range
- Input Noise Voltage Density < 2.4nV/√Hz
- Dual Op Amp (MAX412) Available in 8-Pin DIP/SO
- 28MHz Unity-Gain Bandwidth
- 115dB Min Open-Loop Gain
- 2.5mA Supply Current Per Amplifier
- Single/Dual/Quad

MAXIM

MAX410/412/414 single/dual/quad low noise amplifiers set new noise standards in low-voltage systems. **Noise is 100% tested to guarantee less than 2.4nV/√Hz**. Unity-gain stable bandwidth is 28MHz and slew rate is 4.5V/µs. Other critical parameters for low voltage operation are also guaranteed:

Supply current less than 3.3mA per amplifier
Output voltage swing of ±3.6V into 2kΩ
Supply voltage range of ±2.4V to ±5.5V

The MAX412, unlike other low-noise duals, is available in space-saving 8-pin DIP and SOIC packages.

LOW NOISE OP AMPS

	MAX410/412/414	OP227A	OP270A	LT1028A
Specified at ±5V	YES	NO	NO	NO
Amplifiers per Package	1/2/4	2	2	1
Noise Voltage Density at 1kHz (nV/√Hz max)	2.4	3.9	3.5	1.1
Noise Current Density at 1kHz (pA/√Hz typ)	1.2	0.4	Not Specified	1.0
Supply Current per amp (mA max)	3.3	2.3	2.5	9.5
Input Voltage Range (V_{P-P} min, ±5V Supplies)	7	4	2	2
Output Voltage Swing (V_{P-P} min, ±5V Supplies)	7.3	4	4	4.6
Input Offset Voltage (µV max)	250	80	50	40
Input Bias Current (nA max)	150	35	10	90
GBW (MHz typ)	28	8	6	75
Slew Rate (V/µs typ)	4.5	2.8	2	15
Open Loop Gain (V/µV min)	0.56	1	0.5	7

Note: Specifications for MAX412 with ±5V supplies; all others ±15V unless otherwise noted.

MAXIM

This table compares key specs for common low noise op-amps. As can be seen, the MAX410 family excels when the supply voltage is limited. Especially critical to dynamic range at low supply are noise, input voltage range, and output voltage swing.

MAX406/MAX407 SINGLE/DUAL MICROPOWER OP AMPS

- 1.2µA max Supply Current/Amplifier
- 2.5V to 10V Supply Range
- Input Range Includes Ground
- Outputs Swing Rail-to-Rail
- 0.5mV max Offset Voltage (MAX406)
- 8-Pin DIP and SOIC Packages

MAXIM

The MAX406/MAX407 (single/dual) micropower op amps are designed with battery operation squarely in mind. 1.2µA (per amplifier) supply current represents a dramatic reduction over previous micropower amplifiers. Supply current is held constant over the supply voltage range, so that current does not vary as battery voltage changes.

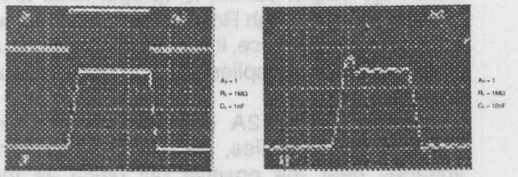
Despite running on only 1.2µA, the MAX406 maintains linearity under loaded conditions. The output can source 2mA when powered from a 9V battery and drives smaller loads when powered from only 3V. Outputs also drive nearly unlimited capacitive loads without oscillating, a very unusual trait for a low power amplifier.

The MAX406/MAX407 are ideal for single-supply operation. Common-mode input range extends from the negative rail to V+ - 1.1V, while the output stage swings rail-to-rail. The MAX406 operates in both compensated mode and decompensated modes. In the compensated mode, the MAX406 is unity-gain stable with a 8kHz bandwidth. Uncompensated (AVCL ≥ 2V/V), the MAX406 guarantees a 40kHz gain-bandwidth. The MAX409 is a decompensated version of the MAX406, offering a guaranteed gain bandwidth product of 80kHz (AVCL ≥ 10V/V) and a slew rate of 40V/ms.

DRIVING CAPACITIVE LOADS

• Stable For Cap. Loads Beyond 10nF

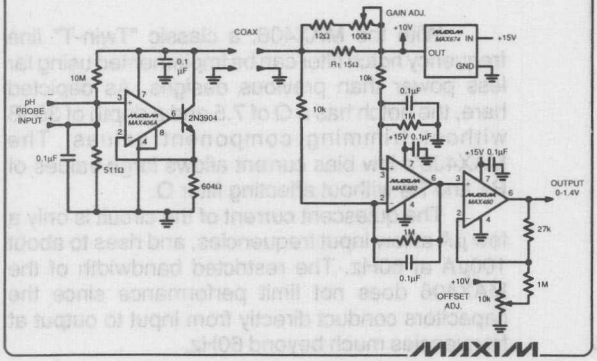
MAX406



MAXIM

For a low- (or micro-) power amplifier to do its job, it must be able to deal with real-world load conditions. This includes capacitive loads, which are often a notorious problem for low power output stages. A large part of the benefit of a low power amp is lost if a buffer must then be added. The behavior of the MAX406 under heavy capacitive loading is shown in these photos. Connected as a unity-gain buffer, the op amp shows no signs of ringing into a 1nF load and only a small amount when driving 10nF.

TWO-WIRE REMOTE pH MEASUREMENT

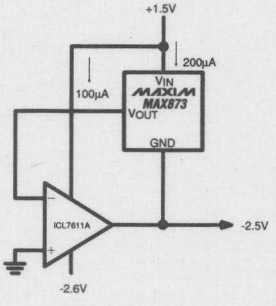


MAXIM

This circuit converts the high-impedance output of a pH probe into a sink current, which is sent down a two-wire cable and converted to a 0-1.4V buffered output voltage. The pH transmitter portion of the circuit, consisting of a 2N3904 transistor and a MAX406 op amp, receives operating power from the output portion: power and signal travel along the same wires. Accuracy is maintained by the extremely low bias current and quiescent current of the input amp. The supply current variation of the MAX406 contributes less than 1mV of output error, which equals 1% of 1 pH unit at the output.

The output stage consists of a MAX482 low power dual op amp and a MAX674 reference. One amplifier, connected as a difference amp, reads the current signal from the input stage as a voltage across the sense resistor, R1. The second amp in the MAX482 provides additional gain and a means of adjusting the output offset. The output provides 0 to 1.4V for a pH of 0 to 14.

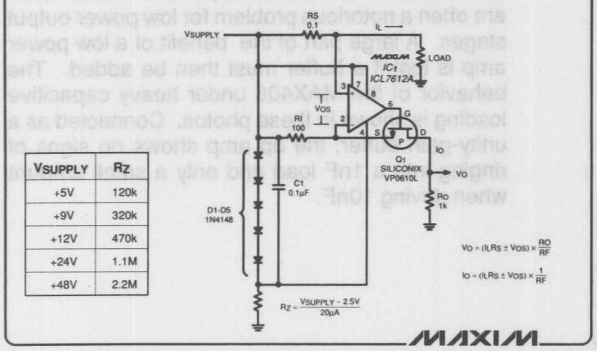
INVERTED REFERENCE CIRCUIT CONSUMES 300µA



MAXIM

By biasing a low power reference (MAX873) so that it sits in the feedback path of a CMOS op amp, a precise -2.5V reference output is generated without using resistors to set inverting amplifer gain. Without these resistors, two sources of error are removed: 1) error that would have resulted from resistor matching in a conventional op amp inverter and, 2) since the circuit output current is supplied by the op amp, load current at the reference IC output is constant so reference load regulation errors are reduced.

MICROPOWER POSITIVE SUPPLY CURRENT MONITOR



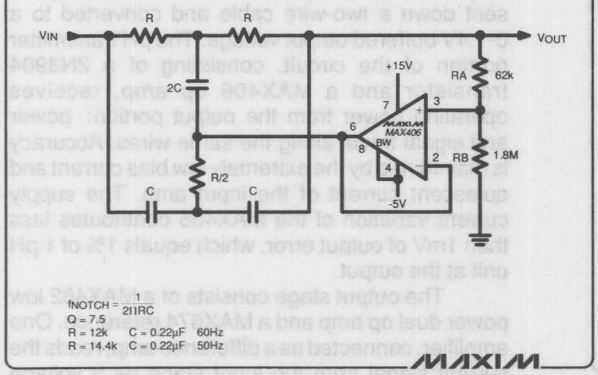
VSUPPLY	RZ
+5V	120k
+9V	320k
+12V	470k
+24V	1.1M
+48V	2.2M

MAXIM

This circuit measures the load current sourced from a positive DC supply and converts it to a ground-referenced signal voltage. It senses in the positive side of the load without using an instrumentation amplifier or precise resistor matching. Output current I_O (proportional to load current) flows through R_O to produce V_O. Since I_O is a true current source, it can be referenced to any level within the supplies, but ground is usually preferred.

The ICL7612A common mode range includes the supplies, so it can sense small voltages near the positive rail (such as those appearing across R_S). R_F should equal 100xR_S or 1000xR_S. The component values shown provide a 0-1V output for a 0 to 1A load current. The ILC7612A uses 20µA and operates from a supply as low as 2.5V. The op amp supply is produced with 5 series diodes biased by R_Z, which can be selected from the table.

MICROPOWER 60Hz NOTCH FILTER

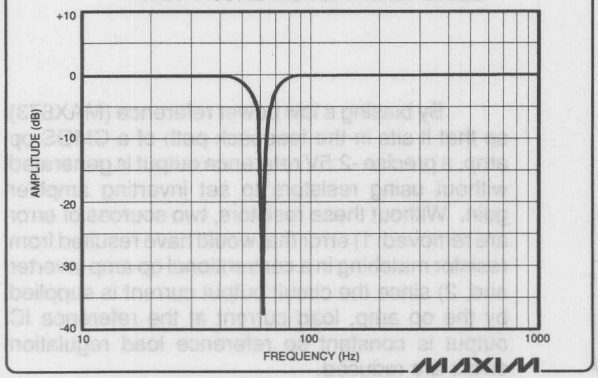


MAXIM

With the MAX406, a classic "Twin-T" line frequency notch filter can be implemented using far less power than previous designs. As depicted here, the notch has a Q of 7.5 and a depth of 35dB without trimming component values. The MAX406's low bias current allows large values of R_A and R_B without affecting filter Q.

The quiescent current of the circuit is only a few µA at low input frequencies, and rises to about 100µA at 60Hz. The restricted bandwidth of the MAX406 does not limit performance since the capacitors conduct directly from input to output at frequencies much beyond 60Hz.

TWIN-T 60Hz NOTCH RESPONSE



MAXIM

- 150kHz Gain Bandwidth
- 1.2µA/Amplifier max Supply Current
- 75V/ms Slew Rate
- Stable for Gains of 10 or Greater
- Single and Dual in 8-Pin DIP and SOIC

MAXIM

75V/ms slew rate while holding tight to a supply current maximum of only 1.2µA. These amplifers differ from the MAX406/407 in that they are compensated for closed-loop gains of 10 or greater.

MAX480
PRECISION MICROPOWER OP AMP

- Operates From Total Supplies of +1.6V to +36V
- Input and Output Voltage Ranges Include Ground
- 16µA Per Amplifier Typ. Supply Current
- 70µV Max Input Offset Voltage
- 1.5µV/°C Max Offset Voltage Drift
- 3nA Max Input Bias Current

MAXIM

MICROPOWER PRECISION OP AMPS: A COMPARISON

	MAX480	OP90
Output Voltage Swing (min)	500µV/4V*	500µV/4V*
Input Offset Voltage (max)	70µV	150µV
Input Bias Current (max)	1nA	15nA
Input Voltage Range (min)	0/4V*	0/4V*
Large Signal Voltage Gain (min)	700k	700k
Slew Rate (min)	5V/ms	5V/ms
Supply Current (max)	15µA	15µA
Input Noise Voltage (typ)	3µVp-p**	3µVp-p**
Gain Bandwidth (typ)	20kHz	20kHz

* V+ = 5V, v- = 0V
** f_O = 0.1Hz to 10Hz, Vs = ±15V

MAXIM

The MAX480 precision micropower op amp combines flexible power-supply capability with superior DC performance over the industry-standard OP90. Input offset voltage is guaranteed over the full supply voltage range. Low input bias current, input offset current, and drift, represents a significant advantage over the highest OP90 grades.

Both input and output voltage ranges include the negative supply rail, allowing "ground-sensing" operation when the amplifers are powered from a single supply. The MAX480 operates with single supplies ranging from 1.6V to 36V, consuming less than 20µA. Despite low quiescent current, the amplifier output can sink or source 5mA.

HIGH-SPEED MICROPOWER OP AMPS

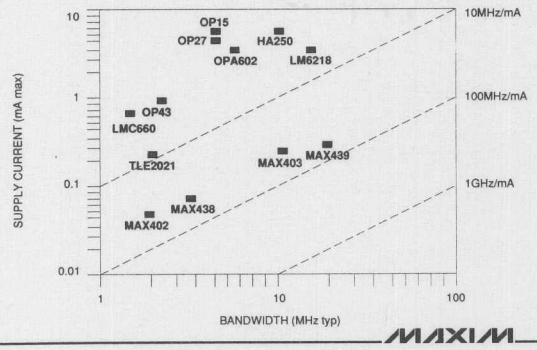
	MAX402	MAX403	MAX438	MAX439
Supply Current	75µA max.	375µA max.	75µA max.	375µA max.
GBW	2MHz	10MHz	6MHz*	25MHz*
Min. GBW	1.4MHz	7MHz	4MHz	18MHz
Slew Rate	7V/µs	40V/µs	10V/µs	48V/µs
Min. Slew Rate	5V/µs	25V/µs	–	–
Operating Supply Voltage	±3V to ±5V	±3V to ±5V	±3V to ±5V	±3V to ±5V
Input Bias Current	±5nA max.	±25nA max.	±5nA max.	±25nA max.
Input Offset Voltage	2mV max.	2mV max.	2mV max.	2mV max.

*Stable for gains ≥ 5

MAXIM

One high performance spec not previously available to designers of low power analog systems with limited supplies (i.e. designers that are "potentially challenged"), is speed. The MAX402 series offers a remarkable combination of high speed and micropower operation. At only 375µA supply current, the 25MHz MAX439 slews at 48V/µs! Specifications of other devices in the family are outlined in the table. The MAX438/439, which are compensated for closed-loop gains above 5, achieve higher speed than the MAX402/403 while using the same supply current. All four devices operate from dual ±3V to ±5V supplies, or from single +6V to supplies, making them ideal for low-power signal processing and remote sensors.

MAX402/403, MAX438/439 BREAK 10MHz/mA BARRIER



MAXIM

FAST LOW-NOISE PRECISION OP AMPS MAX427/437

	MAX427	MAX437 (Min A_{VCL} = 5)
Input Offset (µV max.)	15	15
Input Noise Voltage (0.1Hz to 10Hz, µVp-p max.)	0.18	0.18
10Hz Noise Voltage Density (nV/√Hz max.)	5.5	5.5
10Hz Noise Current Density (pA/√Hz max.)	4.0	4.0
Slew Rate (V/µs min.)	1.7	11
Gain Bandwidth (MHz min.)	5	45

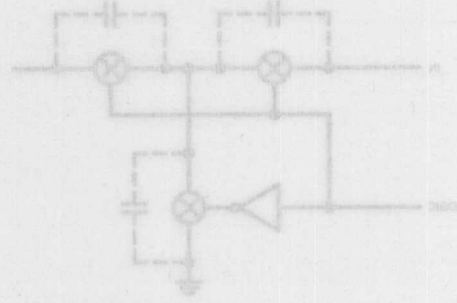
MAXIM

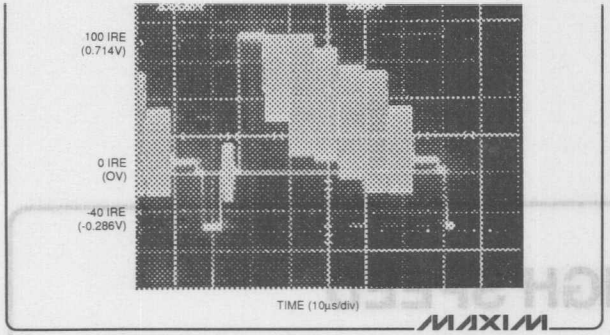
For applications needing high speed **AND** DC precision, the MAX427 and MAX437 provide both without compromise. Offset and open loop gain specs surpass those of the OP27 and LT1007. As the table shows, the MAX437 (NOT an Intel 2nd source!) acheives nine times higher bandwidth than the MAX427 by employing compensation that maintains stablity for gains of 5 or greater.

VIDEO/HIGH SPEED

- **Video MUX/Amplifiers**
- **Building Large Array Crosspoint Switches**
- **High-Speed Buffers and Amplifiers**
- **Wideband Transconductance Amplifiers**
- **Comparators**
  - **High-Speed, Low Power**
  - **Threshold Programmable**
  - **Clocked ECL**

MAXIM





to black (7.5IRE, 0.054V). The two unmodulated pedestals at the ends of each waveform represent black and white. The center pedestals, modulated by the 3.58MHz chrominance subcarrier, represent six primary colors and six secondary colors in descending order of relative luminance amplitude. The 8 pedestals represent, in order: white, yellow, cyan, green, magenta, red, blue and black. When displayed on a screen, this signal appears as a color bar test pattern.

The -40IRE pulse at the start of the waveform is the sync pulse. This starts a new video scan line. The sync pulse is followed by the color burst signal, which is the reference for determining the phase angle of the chrominance signal that follows, and hence the colors in the displayed scan line.

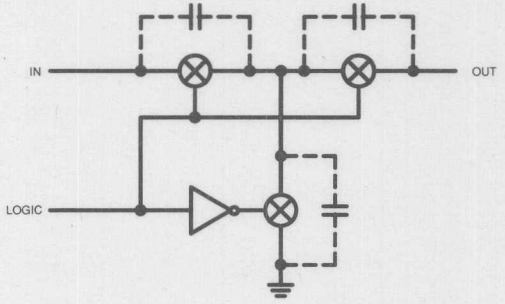
The color bar test signal is often used to measure differential gain and differential phase errors in video circuits. In the test signal, these errors appear as non-linearities in the chrominance signal as the luminance level is varied over its full range (0IRE to 100IRE).

Differential gain and differential phase specifications are critical for color video system components, for they correspond directly to contrast and color distortions in the displayed signal.

DIFFERENTIAL GAIN: The change in the amplitude of the chrominance signal as the luminance signal varies from the blanking level (0V, 0IRE) to the white level (0.714V, 100IRE). Differential gain is usually expressed as a percentage change in gain over the full excursion of the luminance signal.

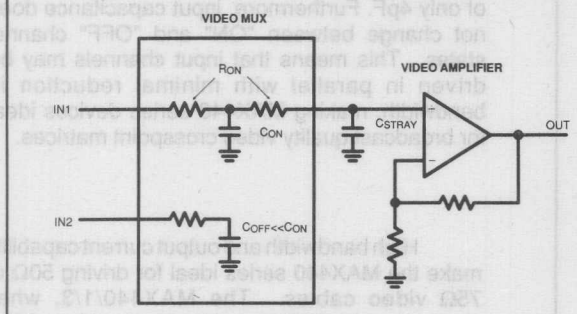
DIFFERENTIAL PHASE: The change in the phase angle of the chrominance signal as the luminance signal is varied from the blanking level to the white level. Differential phase is measured in degrees.

VIDEO "T" SWITCH IMPROVES OFF ISOLATION



A "T" switch configuration reduces crosstalk in a number of Maxim video products. The "T" switch has lower effective feedthrough capacitance and, therefore, higher off isolation and inter-channel isolation than a single switch. When the network is "on", two series FETs between the input and the output turn on. In the off state, these devices turn off, and the junction between them is shunted to ground via a third N-channel FET. This shunts to ground any AC signal coupled through the input FET's drain-to-source capacitance. The MAX456 (8 x 8 crosspoint) achieves 80dB off isolation at 5MHz using this technique.

TRADITIONAL VIDEO MULTIPLEXING



MAXIM

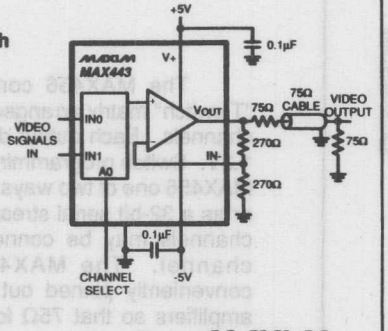
MAXIM VIDEO MUX/AMPLIFIERS

SPECIFICATION	MAX440/1/3	MAX442	MAX453/4/5
NUMBER OF CHANNELS	8/4/2	2	2/4/8
BANDWIDTH (MHz)	160	140	50
DIFFERENTIAL PHASE (degrees)	0.03	0.09	1.2
DIFFERENTIAL GAIN (%)	0.04	0.07	0.5
SLEW RATE (V/µs)	370	250	300
"ON" INPUT CAPACITANCE (pF)	4	4	7
"OFF" INPUT CAPACITANCE (pF)	4	4	3.5

MAXIM

8-PIN VIDEO MUX/BUFFER

- 160MHz Bandwidth
- 0.03° Diff. Phase
- 0.04% Diff. Gain



MAXIM

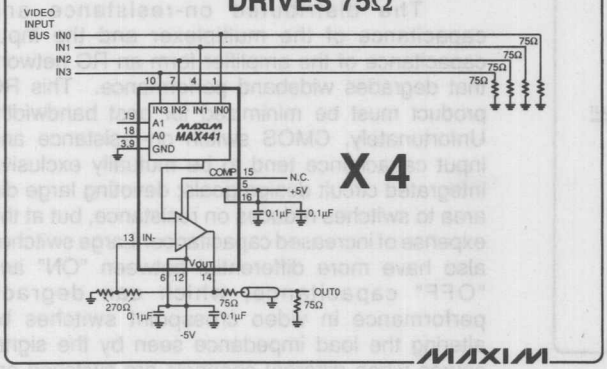
Traditional video multiplexing solutions involve the use of separate video multiplexers and amplifiers. This has several inherent compromises.

The distributed on-resistance and capacitance of the multiplexer and the input capacitance of the amplifier form an RC network that degrades wideband performance. This RC product must be minimized for best bandwidth. Unfortunately, CMOS switch on-resistance and input capacitance tend to be mutually exclusive integrated circuit design goals; devoting large die area to switches reduces on resistance, but at the expense of increased capacitance. Large switches also have more differential between "ON" and "OFF" capacitance, which can degrade performance in video crosspoint switches by altering the load impedance seen by the signal source when different channels are switched on. Conversely, reducing switch size decreases capacitance, but also increases on-resistance.

One effective solution to video multiplexing problems involves integrating the multiplexer and amplifier on a single die. This permits the use of small, low capacitance switches, and reduces high frequency attenuation. Since the high impedance, non-inverting amplifier input is not exposed to the outside world, cross-coupling of high frequencies is also greatly reduced.

Video multiplexer/amplifiers are now available in bandwidths as high as 160MHz and with differential gain and phase spec's that are suitable for broadcast quality color video signals. The MAX440-443 utilize Maxim's new high speed bipolar technology while the MAX453-455 are fabricated in CMOS. The MAX442 (2 channel) is compensated for unity-gain, so its bandwidth and slew-rate are slightly lower than those of the MAX443.

4X4 VIDEO CROSSPOINT DIRECTLY DRIVES 75Ω



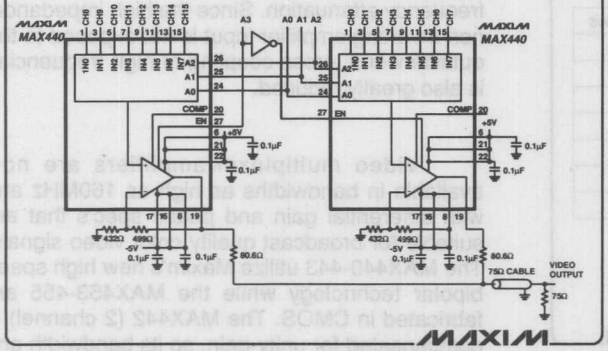
The unique design of the MAX440 family of multiplexer/amplifiers provides input capacitance of only 4pF. Furthermore, input capacitance does not change between "ON" and "OFF" channel states. This means that input channels may be driven in parallel with minimal reduction in bandwidth, making MAX440 series devices ideal for broadcast quality video crosspoint matrices.

High bandwidth and output current capability make the MAX440 series ideal for driving 50Ω or 75Ω video cables. The MAX440/1/3, when connected with 6dB closed loop gain, drives 150Ω (75Ω back terminated cable) to ±3V, at 110MHz. Differential phase and gain are 0.03° and 0.04%.

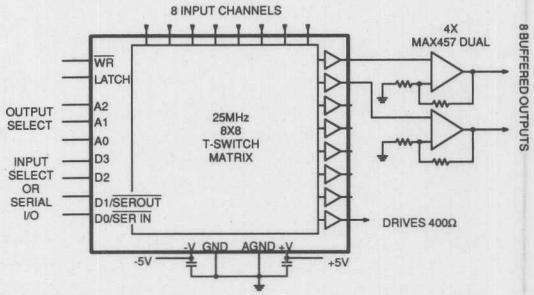
The MAX440 output amplifier can be disabled by driving the EN control input low. When disabled, the output becomes a high impedance load (130kΩ, 15pF) which can easily be driven by other video output. This allows the MAX440 to operate in large matrices where several device outputs are connected in parallel.

The drawing shows a 16 channel video multiplexer with 0dB insertion loss. When no channels in one MAX440 are active, that mux is disabled. Note that outputs are connected after the back- termination resistors so that the active output is isolated from the small capacitive load of the disabled output. Gain is set slightly higher than 6dB to compensate for the voltage divider formed by the disabled amplifier's gain setting and back termination resistors. The back termination resistors are increased to 80.6Ω so that the equivalent resistance at the transmitting end of the cable equals 75Ω.

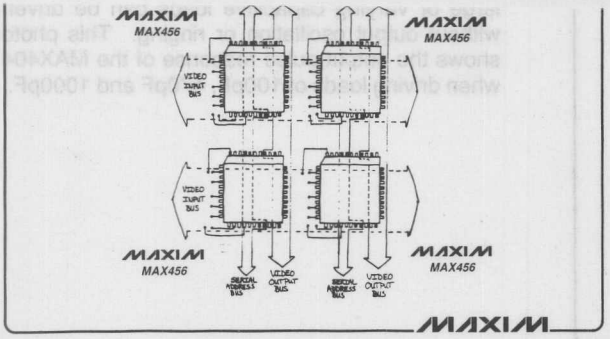
16-CHANNEL VIDEO MUX DRIVES 75Ω AT 110MHz



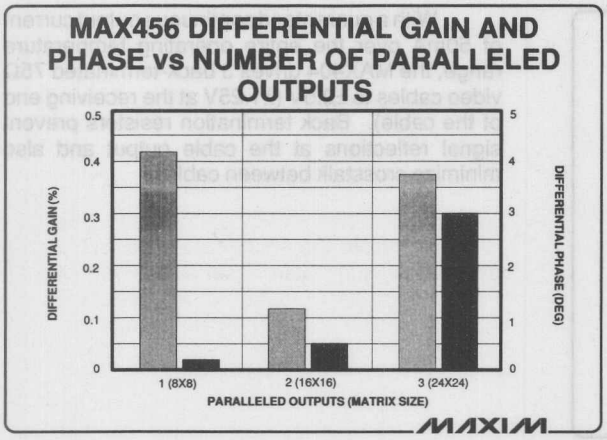
MAX456 8X8 CROSSPOINT



The MAX456 contains a 30MHz 8 x 8 "T switch" matrix arranged for 8 input and 8 output channels. Each output drives 400Ω and 20pF to 1.2V. Switch programming data is loaded into the MAX456 one of two ways: as a 7-bit parallel word, or as a 32-bit serial stream. Each of the 8 output channels may be connected to any one input channel. The MAX456 outputs are also conveniently pinned out to drive MAX457 dual amplifiers so that 75Ω loads can be driven with minimum components.



layout and reduces noise. The PLCC pin configuration allows digital data to be easily routed away from video inputs. In this 16 x 16 crosspoint example, the data bus is perpendiculer to the video input bus to minimize coupling. Typically video signals travel in a separate PCB layer, further reducing digital-analog crosstalk. The low impedance video outputs are much less sensitive to coupled noise than high impedance video inputs, so the output bus can be routed in parallel with data lines with little coupling. Output channels are increased by adding more columns of MAX456's to the matrix, while input channels can be increased by adding more rows of MAX456s.



For MAX456 switch matrices larger than 8 x 8, output buffers must be connected in parallel. Each output must be connected to a second MAX456 output to implement a 16 x 16 matrix while 3 outputs must paralleled for a 24 x 24 crosspoint. Only 1 of the paralleled output buffers can be enabled at any one time. The active buffer must therefor drive the load presented by the disabled buffers in addition to the normal output load. The additional capacitive load (typically 7pF per disabled output), degrades differential gain and phase in the active buffer. The graph shows MAX456 differential gain and phase performance when output buffers are paralleled. The MAX456 16 x 16 crosspoint matrix previously shown can be implemented for NTSC color video systems with very good results. A 24 x 24 video crosspoint with MAX456s provides slightly degraded, but still satisfactory performance for many color systems.

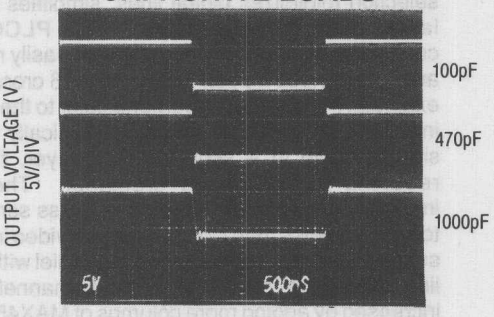
THE MAX404 HIGH-SPEED OP AMP

- **500V/µs Typ. Slew Rate**
- **80MHz Typ. Bandwidth: A_{VCL} = 2**
- **Settles to 0.1% in Typ. 70ns**
- **Differential Gain: 0.05% Typ.**
- **Differential Phase: 0.01° Typ.**
- **Output Current up to 50mA Min.**

MAXIM

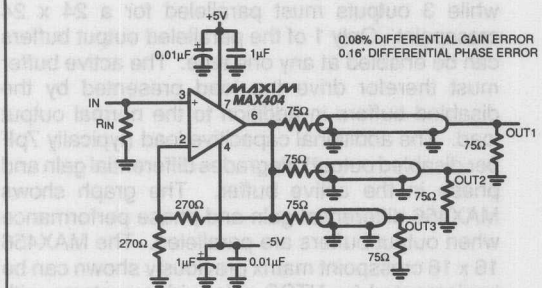
The MAX404 is a high-speed op amp optimized for AC performance, output drive, and stability in the face of varying load conditions. Featuring 80MHz gain-bandwidth, 500V/µs slew rate and 0.01°/0.05% differential phase and gain, this amplifier is ideal for video and other high-speed applications. Unlike current-feedback amplifiers, the MAX404 can be used in virtually all high-speed amplifier applications because it has fully symmetric differential inputs, 70dB CMRR, and 66dB of open-loop gain.

MAX404 STABLE WITH UNLIMITED CAPACITIVE LOADS



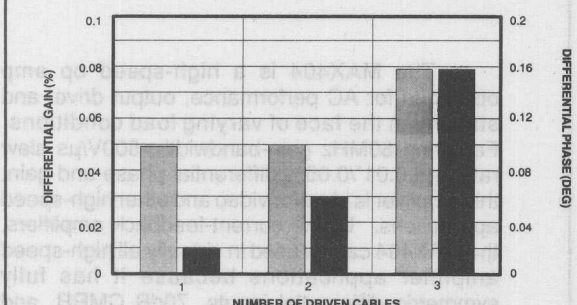
The MAX404 remains stable while driving nearly unlimited capacitive loads. As a result, flash A/D converter inputs, long coaxial cables, and other large or varying capacitive loads can be driven without output oscillation or ringing. This photo shows the output pulse response of the MAX404 when driving loads of 100pF, 470pF and 1000pF.

MAX404 DRIVES THREE 75Ω VIDEO CABLES



With a guaranteed continuous output current of 50mA over the entire operating temperature range, the MAX404 drives 3 back-terminated 75Ω video cables to ±2.5V (±1.25V at the receiving end of the cable). Back termination resistors prevent signal reflections at the cable output and also minimize crosstalk between cables.

MAX404 DIFFERENTIAL GAIN AND PHASE vs NUMBER OF DRIVEN CABLES



The additional load presented by multiple cables can degrade the differential gain and phase performance of video amplifiers. The graph shows MAX404 differential gain (left bar) and differential phase (right bar) errors when driving 1, 2 or 3 video cables. Even when driving 3 cables, differential gain and phase errors are limited to only 0.08% and 0.16 degrees.

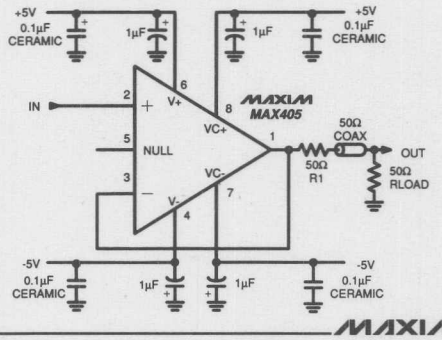
MAX405 HIGH-SPEED BUFFER AMPLIFIER

- **180MHz Bandwidth/650V/µs Slew Rate**
- **0.01° Differential Phase/0.03% Differential Gain**
- **0.99 Min Gain When Loaded Over Temperature**
- **Dirves 4 Back-Terminated 75Ω Loads to ±2.25V**
- **Gain Adjustable Up to 1.1**

MAXIM

The MAX405 buffer combines high speed with precision. It guarantees precisely trimmed gain while continuously driving up to 4 back-terminated 75Ω loads by virtue of only 0.01Ω output resistance. Differential gain and phase performance are ideal for high quality video signal buffering: 0.03% and 0.01°

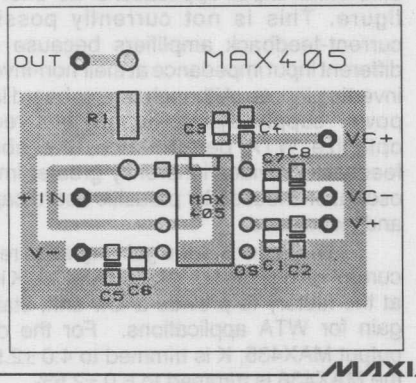
MAX405 CIRCUIT SCHEMATIC FOR BOARD LAYOUT



MAXIM

With IN+, IN- and OUT located on adjacent pins, the pin placement of the MAX405 is very conducive to AC input guarding. Since each of these pins are at the same potential, the low-impedance output can drive a shield ring for the input. The driven shield reduces the effective input capacitance of the MAX405 to less than 1pF, allowing a 100MHz bandwidth with source impedances as great as 1.6kΩ.

MAX405 BOARD LAYOUT



MAXIM

MAX435/MAX436 WIDEBAND TRANSCONDUCTANCE AMPLIFIERS

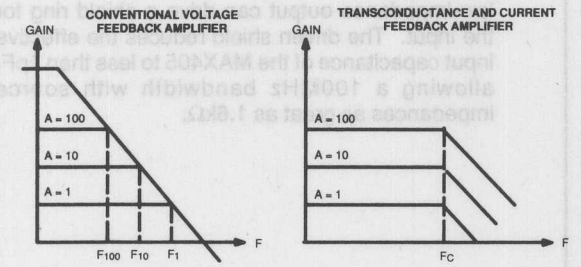
- No Feedback
- 250MHz Bandwidth
- Wideband Gain Independent ot Bandwidth
- 20ns Settling Time
- Fast Overload Recovery
- True Differential High Impedance Inputs

MAXIM

The MAX435/MAX436 Wideband Transconductance Amplifiers (WTA) represent a new design approach to high-speed monolithic amplifiers. A unique architecture allows single-ended or differential signal gain to be set by the ratio of 2 impedances. These amplifiers are also intrinsically stable since they use no closed loop feedback. Phase shift does not affect amplifier stability. The WTA output is a current proportional to the differential input voltage.

Unlike conventional voltage mode amplifiers, the WTA needs no compensation by an internally set dominant pole. Voltage mode amplifiers require this pole to roll off open loop gain and prevent oscillation from high frequency phase shift. Since WTAs forgo this pole, bandwidth is relatively independent of gain, somewhat like current mode amplifiers.

MAX435/MAX436 BANDWIDTH INDEPENDENT OF GAIN

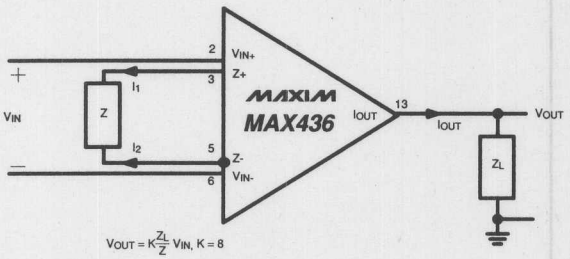


MAXIM

Unlike current-mode feedback amplifiers, Maxim's Wideband Transconductance Amplifier (WTA) has symmetrical inputs with an input impedance of about 400kΩ. This allows true differential input applications as shown in the figure. This is not currently possible with current-feedback amplifiers because of widely different input impedance at their non-inverting and inverting inputs. Although proper board layout and power supply bypassing are still required to optimize WTA performance, the absence of feedback provides inherently greater immunity to oscillation induced by parasitic board capacitance and inductance.

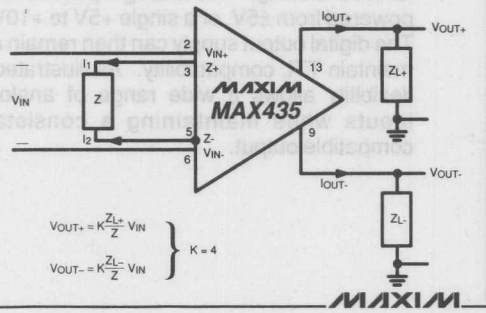
The factor K in the gain equation refers to the current gain of the MAX435/MAX436. K is trimmed at the factory to provide a low drift, stable circuit gain for WTA applications. For the differential output MAX435, K is trimmed to 4.0 ±2.5%. K for the MAX436 is trimmed to 8.0 ±2.5%.

DIFFERENTIAL INPUT WIDEBAND AMPLIFIER



MAXIM

MAX435 DIFFERENTIAL INPUT, DIFFERENTIAL OUTPUT WIDEBAND AMPLIFIER



MAXIM

HIGH-SPEED COMPARATORS

DEVICE	PROP. DELAY (ns)	OUTPUT TYPE	CONFIGURATION	COMMENT
MAX900	8	TTL	Quad	All but MAX901 include latch. Lowest prop. delay x power product in industry.
MAX901			Quad	
MAX902			Dual	
MAX903			Single	
MAX905	2	ECL	Single	Input-output isolation with latch. 3mV threshold resolution.
MAX906			Dual	
MAX910	5	TTL	Single	Digital programming of threshold. Comparator latch included.
MAX911	2	ECL		
MAX9685	1.2	ECL	Single	Comparator latch included, except in MAX9690. All drive 50Ω.
MAX9687	1.4		Dual	
MAX9690	1.3		Single	
MAX9686	6	TTL	Single	Comparator latch included.
MAX9698			Dual	

MAXIM

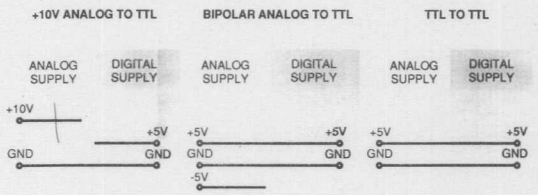
MAX900-903 HIGH-SPEED LOW-POWER COMPARATORS

- **8ns Typ. Propagation Delay**
- **3.5mA Max Supply Current per Comparator**
- **Separate Analog and Digital Supplies**
- **Flexible Analog Supply: +5V to 10V or ±5V**
- **Input Range to Negative Supply -100mV**
- **TTL Compatible Outputs**
- **TTL Compatible Latch Inputs**
- **Single, Dual, and Quad Versions**

MAXIM

The MAX900-MAX903 analog comparators provide high speed performance at a fraction of the supply current of existing devices. Typical propagation delay is only 8ns, while the maximum current consumption is less than 3.5mA per comparator. Power can be supplied from separate analog and digital supplies or from a single supply. Analog input range includes the negative rail, allowing ground sensing when powered from a single supply.

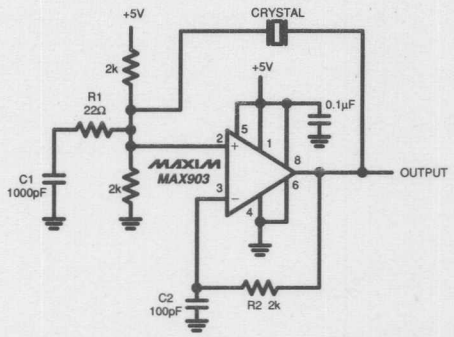
POWER SUPPLY FLEXIBILITY SIMPLIFIES LEVEL SHIFTING MAX900-903



MAXIM

Independent analog and digital supply connections on the MAX900-MAX903 minimize noise coupling from digital to analog circuitry. Separate supply connections also provide flexibility for level shifting. The analog input section can be powered from ±5V, or a single +5V to +10V supply. The digital output supply can then remain at +5V to maintain TTL compatability. As illustrated, supply flexibility allows a wide range of analog signal inputs while maintaining a consistant TTL compatible output.

LOW POWER CRYSTAL OSCILLATOR

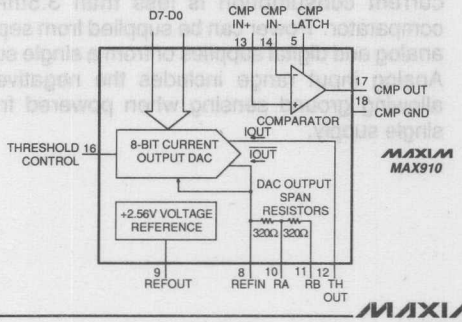


MAXIM

Many digital and mixed-mode systems require a stable crystal clock source. "Canned" oscillators are of course very common for standard frequencies (10MHz, 20MHz, etc), but are difficult to find in high non-standard frequencies. Also canned oscillators frequently require buffers for heavy loads. The MAX903's 10ns propagation delay and large open-loop gain are well suited to crystal oscillator applications. This circuit will provide a clock source with crystals ranging from 10MHz to 25MHz, while driving a 500Ω load.

The R1-C1 network reduces high frequency gain to prevent oscillation at undesired cystal overtone frequencies. R1 and C1 can be eliminated for crystals below 10MHz. C2 and R2 roll off low frequency gain and prevent overtone crystals from oscillating at their fundamental frequency. For clock sources below 10MHz, C2 may have to be increased.

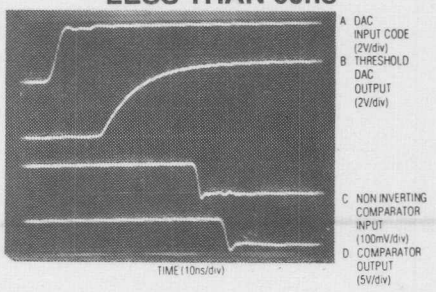
HIGH-SPEED, THRESHOLD-PROGRAMMABLE VOLTAGE COMPARATORS



MAXIM

The MAX910 and MAX911 high-speed comparators include an on-chip DAC to program the comparator threshold. The MAX910 comparator has a single TTL-compatible output (8ns prop delay); the MAX911 has differential ECL-compatible output (4ns prop delay). Both comparators have latchable outputs. The threshold level is set in either 10mV or 20mV steps (2.56V or 5.12V full-scale range) as set by the DAC and two on-chip span resistors. The threshold can be updated within 50ns. The MAX910 and MAX911 have separate analog and digital ground for noise rejection. The devices are normally powered from ±5V, although the traditional -5.2V ECL power rail is also permissible.

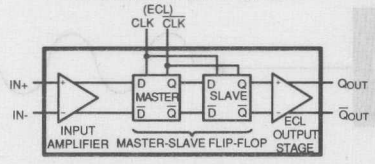
THRESHOLD UPDATE AND COMPARATOR OUTPUT IN LESS THAN 60ns



MAXIM

The internal DAC in the MAX910/MAX911 typically settles in 50ns. This settling time, combined with propagation delays less than 10ns (5ns for the MAX911, 10ns for the MAX910) allow a threshold voltage update and input comparison in less than 60ns. Quick response to threshold voltage changes make the MAX910/911 excellent front-end devices for multi-channel, high-speed automatic test or data acquisition systems.

MAX905/MAX906 HIGH SPEED ECL COMPARATORS

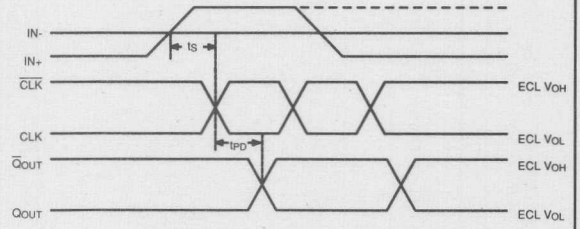


- **3mV Resolution**
- **4ns Max Set-Up Time/1ns Max Hold Time**
- **3ns Max Propagation Delay (Independent of Overdrive)**
- **MAX905 Single/MAX906 Dual**

MAXIM

By adding a high-speed master-slave flip-flop, output oscillation can be eliminated in many fast comparator applications. A clocked architecture eliminates parasitic coupling between inputs and outputs, and consequently eliminates the major source of instability. Clocking also frees high-speed comparator propagation delay from its depedence on input overdrive. The MAX905 single, and MAX906 dual, high speed comparators include clock inputs on chip.

MAX905/MAX906 TIMING



MAXIM

The clocked design can confuse normal comparator terminology when describing specs. Normally "propagation delay" is the most important comparator speed spec. In the MAX905/906, propagation delay (t_{PD}) describes the delay from a **clock edge** (not the input) to a valid output (see timing diagram). Prop delay plus setup time (t_S) is the total time from input change to output (7ns max). **BUT REMEMBER** that the comparator output, although delayed by 3ns (typ.), is still the correct decision about the analog input at the time of the clock edge (within 2ns).

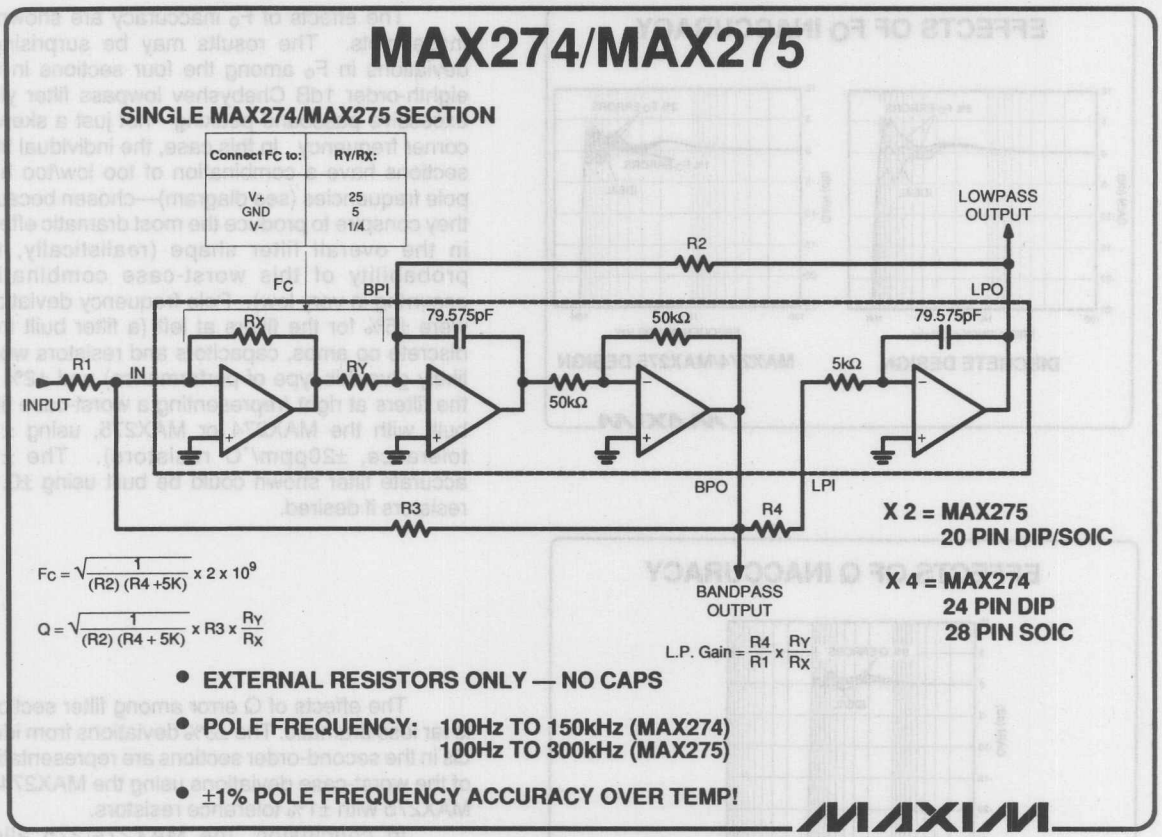
ACTIVE FILTERS



- **Continuous "MF10" - No Clock**
- **DC Accurate Filter Techniques**
- **8th Order, Fixed Shape Switched-Cap Filters**
- **Building Frequency-Adjustable Continuous Filters**

MAXIM

MAX274/MAX275



- **EXTERNAL RESISTORS ONLY — NO CAPS**
- **POLE FREQUENCY: 100Hz TO 150kHz (MAX274)**
  100Hz TO 300kHz (MAX275)
- **±1% POLE FREQUENCY ACCURACY OVER TEMP!**

MAXIM

Active filters built from discrete components—op amps, resistors, and capacitors—tend to suffer from component accuracy and drift problems, as well as layout sensitivities. Consistent results over temperature require use of expensive low-drift capacitors and careful attention to layout. For higher order filters, these sensitivities may become overwhelming when trying to maintain a consistent filter shape.

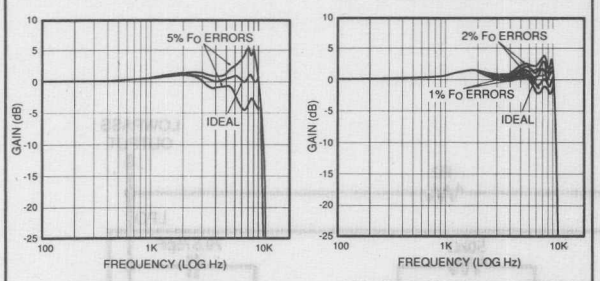
While switched capacitor filters offer a solution to these problems by employing accurately-trimmed switching capacitors to control filter characteristics, they have several limitations: the most serious are Nyquist bandwidth limitations, switching noise (several millivolts at the switching frequency), aliasing, and higher distortion.

For applications requiring filters that are not switched, the MAX274 and MAX275 are the most highly integrated, accurate, and cost-effective means of building continuous filters available. The MAX274/MAX275 are integrated linear filter "building blocks". They consist of a network of op amps and very accurately trimmed, low-drift capacitors. Adding four external resistors per second-order section (a fourth-order lowpass filter would require eight resistors, for example) completes the lowpass or bandpass filter. All-pole classic filters, such as Butterworth, Chebyshev, and Bessel are realizable. The MAX274/MAX275 filters overcome many of the problems which led designers away from continuous designs to switched-capacitor filters. Therefore these integrated continuous filters are worth a fresh look.

WHAT IS FILTER ACCURACY AND WHY IS IT IMPORTANT?

Most people associate pole frequencies (F_o) with cutoff frequency—the -3dB point—of a lowpass filter, or the center frequency of a bandpass filter; Q is related to the amount of peaking or passband ripple. Therefore deviations in F_o and Q of a filter "should" correspond to deviations in -3dB point and passband peaking, respectively. This line of thinking is correct for a single second-order section but reduces to a loose correlation at best for multiple-order filters. Most useful filters consist of multiple sections, each with a different pole frequency and Q, connected in series to produce the overall desired response. Small F_o and Q inaccuracies in any of the cascaded filter sections can have significant (and surprising) consequences for the overall shape of the filter.

EFFECTS OF F_O INACCURACY

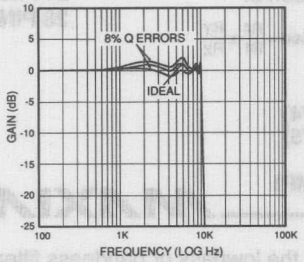


DISCRETE DESIGN MAX274/MAX275 DESIGN

MAXIM

The effects of F_O inaccuracy are shown in these plots. The results may be surprising: deviations in F_O among the four sections in the eighth-order 1dB Chebyshev lowpass filter yield excessive passband peaking—not just a skewed corner frequency. In this case, the individual filter sections have a combination of too low/too high pole frequencies (see diagram)—chosen because they conspire to produce the most dramatic effects in the overall filter shape (realistically, the probability of this worst-case combination occurring is very low). Pole frequency deviations were ±5% for the filters at left (a filter built from discrete op amps, capacitors and resistors would likely give this type of performance) and ±2% for the filters at right (representing a worst-case filter built with the MAX274 or MAX275, using ±1% tolerance, ±20ppm/°C resistors). The ±1% accurate filter shown could be built using ±0.1% resistors if desired.

EFFECTS OF Q INACCURACY

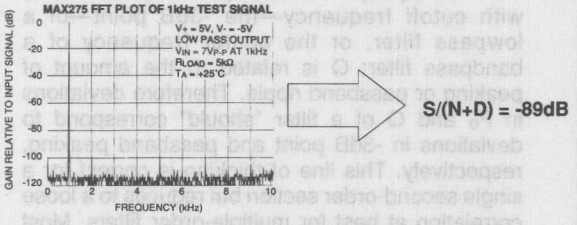


MAXIM

The effects of Q error among filter sections is far less dramatic. The ±8% deviations from ideal Qs in the second-order sections are representative of the worst-case deviations using the MAX274 or MAX275 with ±1% tolerance resistors.

In conclusion, the MAX274/275 allow superior accuracy, important for achieving the expected filter shape. Inaccuracies of op amps, resistors, and capacitors make it difficult for a discrete filter to match the performance of the MAX274/275.

MAX274/MAX275 NOISE/DISTORTION



BANDWIDTH	NOISE*	PEAK OUTPUT SWING
10Hz - 10kHz	42μVRMS	±3.5V

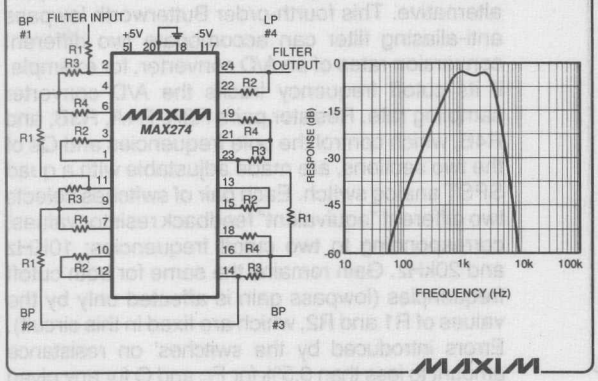
DYNAMIC RANGE = 96dB

*MAX275 FO = 10kHz
Q = .707
LP OUTPUT

MAXIM

The MAX274/275 state-variable topology—and their use of low noise amplifiers as inverters—allows low distortion and good noise performance—as low as -89dB Signal-to-Noise + Distortion Ratios (tested with 1kHz test signal). The dynamic range of these devices is 96dB.

C-MESSAGE FILTER



MAXIM

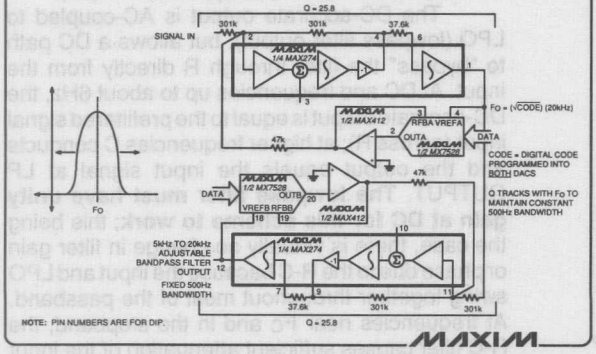
An application which takes advantage of the MAX274's low noise is the C-Message weighting filter. This bandpass filter's shape simulates the response of the human ear; it is used in telecommunications applications for audio noise measurements. Using a single MAX274, the C-Message filter is constructed by cascading three second-order bandpass sections together with a second-order lowpass section, all done using a single MAX274. The performance of these filters is outstanding: 2.5µVrms in-band noise and output swings of 5VPP provide nearly 117dB dynamic range (operating from 5V supplies).

C-MESSAGE FILTER POLE/Q COEFFICIENTS AND RESISTOR VALUES

FILTER SECTION	POLE FREQUENCY	Q	R1	R2	R3	R4
BP #1	312.741	0.6540	845k	6.34M	825k	6.34M
BP #2	933.761	1.2027	274k	2.15M	511k	2.15M
BP #3	2541.886	1.7026	75k	787k	261k	768k
LP #4	3492.778	2.7316	133k	576k	309k	562k

MAXIM

ADJUSTABLE CONTINUOUS BANDPASS FILTER

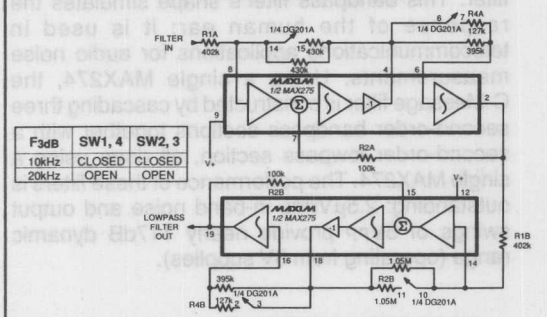


MAXIM

The addition of multiplying D/A converters provides digital tuning capability to continuous filters. In the fourth-order bandpass filter shown using the MAX275, the center frequency is proportional to the parallel digital code applied to the D/A converters. $F_C = \sqrt{code}$ (20kHz), where Fc is the center frequency and "code" is normalized to 16/256 ...255/256 (the four LSBs are tied high to avoid excessive attenuation of the feedback signal). Because the converters change code simultaneously, they assure a smooth transition between center frequencies.

Code FF_H, for instance, centers both 2nd-order filter sections at 20kHz with Qs of 25.8, resulting in a net (cascaded) Q of 40 and a bandwidth of 500Hz. Lower codes attenuate the feedback signal between the lowpass output and the input of that section, reducing the center frequency and Q in proportion across the range 5kHz to 20kHz. The passband remains a constant 500Hz. Bandpass gain is unaffected.

ADJUSTABLE CONTINUOUS LOWPASS FILTER

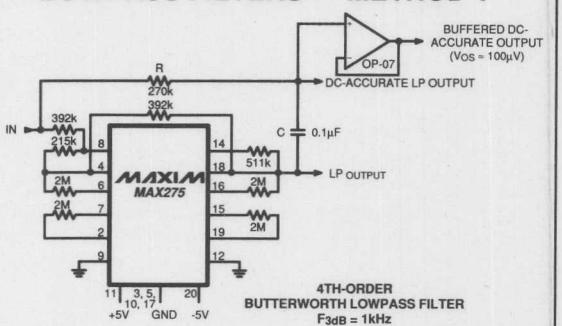


F_{3dB}	SW1, 4	SW2, 3
10kHz	CLOSED	CLOSED
20kHz	OPEN	OPEN

4TH-ORDER BUTTERWORTH

MAXIM

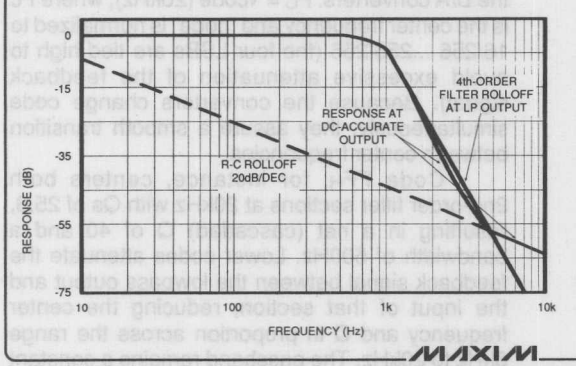
REMOVE DC OFFSET FROM LOWPASS FILTERS — METHOD 1



4TH-ORDER BUTTERWORTH LOWPASS FILTER
F_{3dB} = 1kHz

MAXIM

OFFSET REMOVAL — METHOD 1



MAXIM

If just a few adjustable frequencies are required, analog switches offer a simpler alternative. This fourth-order Butterworth lowpass anti-aliasing filter can accomodate two different conversion rates of an A/D converter, for example, if its cutoff frequency tracks the A/D converter sampling rate. Resistor pairs R3A, R4A, R3B, and R4B, which control the pole frequencies and Qs of the two sections, are made adjustable with a quad SPST analog switch. Each pair of switches selects two different "equivalent" feedback resistor values, corresponding to two cutoff frequencies: 10KHz and 20kHz. Gain remains the same for both cutoff frequencies (lowpass gain is affected only by the values of R1 and R2, which are fixed in this circuit). Errors introduced by the switches' on resistance amount to less than 0.5% for F_C and Q for any given section.

DC OFFSET REMOVAL

Any higher-order filter exhibits some DC offset at its output—accumulated from a large number of cascaded amplifiers. Analog circuitry and data converters downstream from the filter may require removal of this offset to maintain good dynamic range. Trimming the filters by summing a DC compensation voltage offset into the input is usually not cost-effective in production. Simple R-C AC-coupling will not work with lowpass filters which must pass DC. Some solutions follow.

DC OFFSET REMOVAL- METHOD 1:

The simple scheme shown here utilizes a resistor and capacitor to restore "perfect" DC accuracy to a lowpass filter. The R-C pole is set at least two decades below the lowpass filter pole:

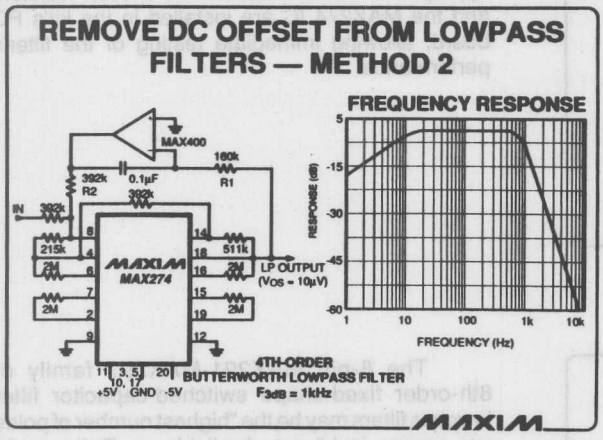
$$\frac{1}{2\pi RC} < \frac{F_C}{100}$$

where Fc = -3dB frequency of the lowpass filter. In this case, a 4th-order Butterworth lowpass filter built using the MAX275 has F_C = 1kHz, with $1/(2\pi RC)$ = 6Hz. The output may be buffered, if required, using a low offset op amp, such as the OP-07 (V_{OS} = 10µV + (I_{BIAS})(270K) = 91µV).

The DC-accurate output is AC-coupled to LPO (lowpass filter output), but allows a DC path to "bypass" the filter through R directly from the input. At DC and frequencies up to about 6Hz, the DC-accurate output is equal to the prefiltered signal input (across R); at higher frequencies C conducts and the output equals the input signal at LP OUTPUT. **The lowpass filter must have unity gain at DC for this scheme to work**; this being the case, there is virtually no change in filter gain or phase due to the R-C because the input and LPO swing together throughout most of the passband. At frequencies near F_C and in the stopband, the R-C filter causes sufficient attenuation of the input signal that the original filter shape is maintained.

However, at very high frequencies, attenuation is ultimately limited by the 20dB/decade rolloff rate of the R-C. See response plot.

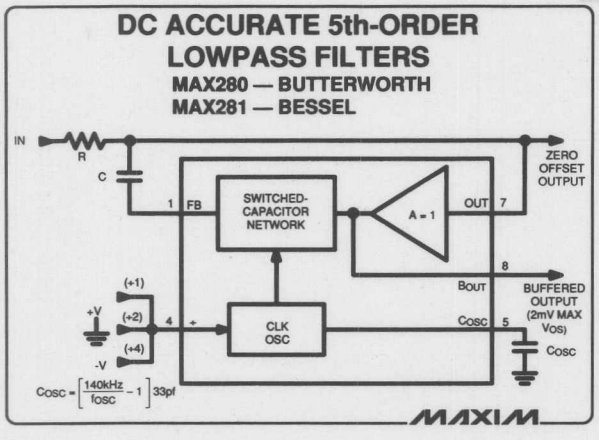
Input step response is virtually unaffected by the R-C. As long as this time constant is much longer than the filter's signal delay from input to output, there is no net charging of C.



DC OFFSET REMOVAL- METHOD 2:

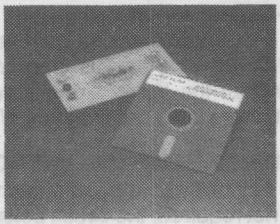
For lowpass applications where response to DC is not required, the circuit below is an excellent alternative. The op amp integrator forces the DC voltage at the filter output to zero (actually, to within the offset voltage of the op amp) by feeding back a current to the filter's input summing node. In effect, the feedback adds a highpass filter to the overall response, with its -3dB point at 10Hz; the result is a bandpass filter, as shown in the Bode plot. To move the highpass -3dB point lower in frequency, either increase the value of R1, or decrease the feedback gain by increasing the value of R2. The bandwidth requirement of the op amp is very low—100Hz bandwidth is more than enough—so a low bandwidth precision op amp may be used. Also, keeping the op amp out of the direct signal path eliminates added distortion effects possible with the buffer of the previous method. For this reason, this scheme is commonly found in audio circuits.

This technique may be used to correct offsets in bandpass filters as well, by feeding back a current to the filter's bandpass input (BPI) pin. Advantages offered by this method, compared with AC coupling the output and buffering with an op-amp, are that signal distortion is not increased and low bandwidth op amps can be used.



The MAX280/281 are "zero offset" switched-capacitor filters. These fifth-order fixed-shape (Butterworth/Bessel) lowpass filters utilize a unique topology using a resistor and capacitor to isolate the DC signal path from the IC, thereby introducing no DC offset. Since these are switched-capacitor filters, the corner frequency is set by providing an external clock switching at a frequency 100 times the desired -3dB point (an internal clock is also available). The external R-C also serves as an anti-aliasing filter for the MAX280/281. Allowable cutoff frequencies range from 0.1Hz to 20kHz.

MAX274 EVALUATION KIT

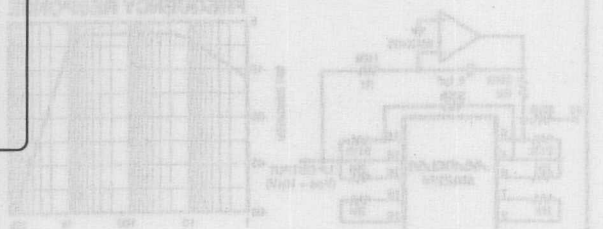


INCLUDES:

- **FILTER DESIGN SOFTWARE**
- **PC BOARD WITH LAYOUT AND MAX274**
- **FULL DOCUMENTATION**

MAXIM

The MAX274 EV Kit allows fast circuit design and evaluation of MAX274-based filters. The kit includes software to calculate filter order, poles, and Qs for the classic filter of choice (Butterworth, Chebyshev, or Bessel); it also plots frequency, phase and delay responses, and it chooses the appropriate resistor values. The chosen resistors and the MAX274 IC are installed in the kit's PC board, allowing immediate testing of the filter's performance.

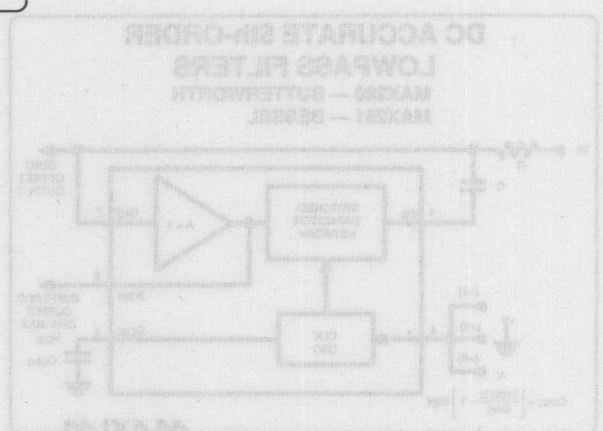


MAX291-MAX297 LOWPASS FILTER FAMILY

PART	TYPE	Fc RANGE	$\frac{F_{CLK}}{F_{CORNER}}$ RATIO
MAX291	BUTTERWORTH	0.1Hz - 25kHz	100:1
MAX292	BESSEL	0.1Hz - 25kHz	100:1
MAX293	ELLIPTIC 1:5 TRANS RATIO	0.1Hz - 25kHz	100:1
MAX294	ELLIPTIC 1:2 TRANS RATIO	0.1Hz - 25kHz	100:1
MAX295	BUTTERWORTH	0.1Hz - 50kHz	50:1
MAX296	BESSEL	0.1Hz - 50kHz	50:1
MAX297	ELLIPTIC 1:5 TRANS RATIO	0.1Hz - 50kHz	50:1

MAXIM

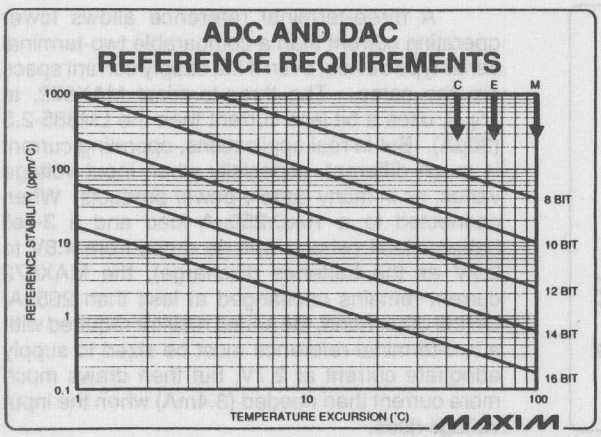
The 8-pin MAX291-MAX297 family of 8th-order fixed-shape switched-capacitor filter lowpass filters may be the "highest number of poles per square inch" yet. Available as Butterworth, Bessel or Elliptic filters, they achieve a high degree of shape accuracy, due to ladder filter design, and allow corner frequencies in the range of 0.1Hz to 50kHz.



REFERENCES

- **3V and 5V Supply Low-Dropout References**
- **Ultra-Close Tolerance, Low Drift References**

MAXIM



References commonly provide the stable voltage sources required by ADCs and DACs to maintain accuracy. Pictured is a graph showing just how stable a reference must be to ensure ADC or DAC accuracy to within 1LSB over temperature. Note the horizontal axis is EXCURSION from an initial temperature; arrows indicate the points of maximum temperature excursion from 25°C, and the required reference stability, when operating in the commercial, extended, and military temperature ranges.

MAX676/677/678

- 4.906V, 5V and 10V Precision References
- 2ppm/°C Max Temperature Drift
- 10ppm/1000 Hours Max Long Term Drift
- ±0.016% Voltage Tolerance Over All Temp. Ranges
- On-Chip ROM Cells Maintain Calibration Over Temp.
- Unique ID Code Guarantees Drift Test

MAXIM

proprietary technique using a factory-programmed on-chip ROM calibrates the reference at specific temperatures and reduces temperature drift to less than 2ppm/°C. Each part carries a unique identification code allowing temperature and long-term drift specifications for each device to be monitored.

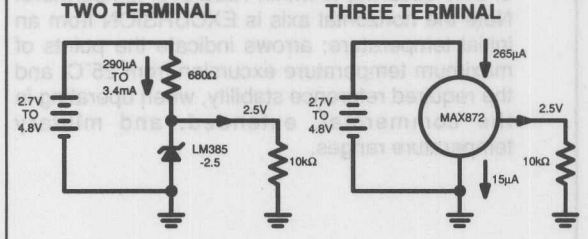
LOW DROPOUT REFERENCES FOR 3V AND 5V SUPPLIES

- Low Dropout: 2.6V Input, 2.5V Out (MAX872)
  4.3V Input, 4.096V Out (MAX874)
- Low Quiescent Current—15µA Max Over Temperature
- 40ppm/°C Max Temperature Drift
- Tolerance: 0.2% (MAX872) and 0.1% (MAX874)

MAXIM

The MAX872/874 low dropout regulators minimize power consumption while still providing stable output voltages over temperature. The MAX872 provides 2.5V from supplies as low as 2.6V, working nicely in 3V-powered systems (with ±10% supply accuracy). The MAX874, designed for 5V systems, provides a 4.096V output from a 4.3V supply. Both references source 500uA while using extremely low quiescent current (15µA max).

THREE-TERMINAL REFERENCES REDUCE SUPPLY CURRENT



MAXIM

A three-terminal reference allows lower operating current than a comparable two-terminal zener type device, even if the supply current specs are the same. The three-terminal MAX872, at 15µA, uses a bit less current than the LM385-2.5 (30µA). But in real applications, operating current is much different, especially when input voltage varies, as in many battery power products. When connected to a 10kΩ/250µA load and a 3-cell battery stack (whose voltage drops from 4.8V to 2.7V as the batteries discharge), the MAX872 current remains unchanged at less than 265µA. On the other hand, the series resistor required with a two-terminal reference must be sized to supply adequate current at 2.7V, but then draws much more current than needed (3.4mA) when the input voltage rises.

INDUSTRY STANDARD REFERENCE UPGRADES MAX873/875/876

	Voltage	Max Tolerance (25°C)	Max Drift (ppm/°C)	Max Supply Current Over Temp. (µA)
MAX873	2.5V	±0.06%	7	375
REF-43	2.5V	±0.05%	10	600
MAX875	10V	±0.04%	7	375
REF-01	10V	±0.3%	8.5	1400 (@ 25°C)*
MAX876	5V	±0.03%	7	375
REF-02	5V	±0.3%	8.5	1400 (@ 25°C)*

* Not specified over temp.

MAXIM

The MAX873/5/6 Voltage References are upgrades for the REF-43 (2.5V), REF-01 (10V) and REF-02 (5V). Inprovements have been made in supply current, drift, and initial tolerance.

MAXIM'S REFERENCES

Part Number	Output Voltage (V)	TempCo (ppm/°C)	Output Voltage Accuracy (@ +25°C)	Supply Voltage (V)	Supply Current (mA, @ +25°C)	Features
ICL8069	1.23	10	±2.5%	--	0.05-5	2 Terminal Bandgap
REF01	10	8.5	±0.3%	13-33	1.4	Trim Input
REF02	5	8.5	±0.3%	8-33	1.4	Temp Output
MX580	2.5	10	±0.4%	4.5-30	1.5	10mA Output
MX581	10	5	±0.05%	12.5-30	1.0	10mA Output
MX584	10/7.5/5/2.5	5	±0.05%-.1%	4.5-30	1.0	Pin Programmable
MX2700	10	3	±0.025%	13-18	14	Precision
MX2701	-10	3	±0.025%	(-13)-(-18)	14	Precision
MX2710	10	1	±0.01%	13-18	14	Precision
MAX670	10	3	±0.025%	13.5-16.5	14	4 Terminal Sensing
MAX671	10	1	±0.01%	13.5-16.5	14	4 Terminal Sensing
MAX674	10	12	±0.15%	13-33	1.4	Precision, Low Cost
MAX675	5	12	±0.14%	8-33	1.4	Precision, Low Cost
MAX676	4.096	1.7	±0.01%	4.75-18	10	Lowest Drift
MAX677	5	1.7	±0.01%	5.8-18	10	Lowest Drift
MAX678	10	1.7	±0.01%	10.8-18	10	Lowest Drift
MAX872	2.5	40	±0.20%	2.6-20	0.010	Low-Dropout, Low I_Q
MAX874	4.096	40	±0.10%	4.2-20	0.010	Low-Dropout, Low I_Q
MAX873	2.5	7	±0.06%	4.5-20	0.280	REF-43 Upgrade
MAX875	5	7	±0.04%	7-20	0.280	REF-02 Upgrade
MAX876	10	7	±0.03%	12-20	0.280	REF-01 Upgrade

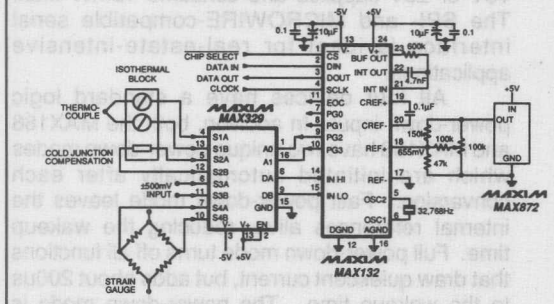
MAXIM

ADCs & DACs

- Low Power
  - High-Resolution Integrating ADCs
  - High-Speed with Power-Down
- 12- and 14-Bit SAR ADCs
- AC Characteristics of Multiplying DACs
- New Multiplying DACs
- Quad and Octal DACs

MAXIM

18-BIT SERIAL ADC CONTROLS EXTERNAL MUX



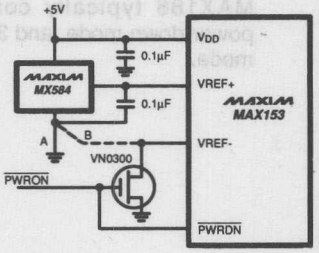
MAXIM

The MAX132 18-bit-plus-sign integrating A/D runs on less than 125µA and can perform up to 100 conversions per second. It has one differential input channel, but features four unique serially addressable digital outputs (PG0-PG3) which can select a mux channel, program gain, or set an external filter via the A/D's serial input. To save power the A/D or external circuitry can also be shutdown. When shut down, the MAX132 draws only 5µA. The MAX135, a parallel-output A/D similar to the MAX132, omits the PG0-PG3 outputs, and is a 15-bit converter. Software averaging of its three "Super LSBs" can increase effective resolution.

EV KIT + 8032

FAST 8-BIT ADC WITH POWER DOWN FOR BATTERY-POWERED SYSTEMS

- 1µA Shutdown Mode
- Zero Wakeup Time
- 1 Megasample per Second
- Internal Track/Hold



MAXIM

A traditional tradeoff in analog design is between speed and power. A way around this is to reduce supply current when circuitry is not in use. The MAX153, a 1 MSPS 8-bit ADC, has power-down, making it ideal for fast data conversion in battery- powered systems. The ADC consumes 1µA when shut down and operates from either single +5V or ±5V supplies. Shutdown can be implemented three ways:

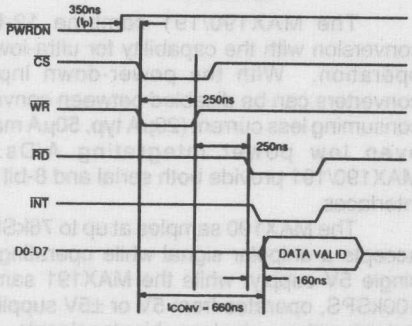
1) Simply connect $\overline{PWRDN}$ to a logic line. This way, the MAX153 has nearly zero wake-up time; you need only wait the normal minimum time between conversions (t_p = 350ns) to ensure a valid conversion after power-up. Zero wake-up time reduces the average current. While in shutdown, the ADC draws about 1µA; however, the A/D still presents a 2mA reference load.

2) An external MOSFET disconnects the MAX153 VREF- pin from ground during shutdown, reducing total current to the 175µA drawn by the reference. In this scheme, connection A is made (B is open). A 0.1µF reference bypass capacitor between VREF+ and ground remains charged during shutdown to reduce reference risetime after power up.

3) In the third approach, the MOSFET removes both power and the MAX153 load from the reference. This approach is implemented with connection B. By connecting the reference, bypass cap, and VREF- to the MOSFET drain, powerdown current is reduced to zero. This affords the least power consumption, but the longest delay when the circuit leaves power down. After power up, the reference needs about 250µs to charge the compensation capacitor and settle.

VALID DATA 1µs AFTER POWER UP

MAX153



MAXIM

- **+5V or ±5V Operation**
- **130kSPS – Track/Hold Included**
- **12mW Max Power Consumption**
- **Serial Interface – SPI & Microwire Compatible**

	MAX186	MAX187	MAX188	MAX189
Input Channels	8	1	8	1
Internal Reference	Yes	Yes	No	No
Package	20-Pin	8-Pin	20-Pin	8-Pin

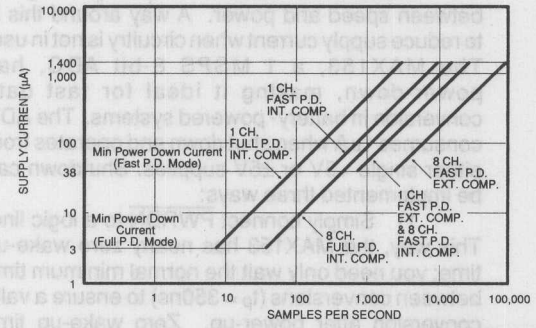
MAXIM

interface is ideal for real-estate-intensive applications.

All four devices have a standard logic power-down input. In addition, both the MAX186 and MAX188 have two unique power-down modes which are initiated automatically after each conversion. Fast power-down mode leaves the internal references alive, reducing the wakeup time. Full power-down mode turns off all functions that draw quiescent current, but adds about 200us to the wakeup time. The power-down mode is selected via the serial input.

The MAX186 and MAX188's auto power-down modes save power when operating at less than the maximum sample rate. The graph shows current consumption vs. sample rate for the two power-down modes and reference compensation methods. As the ADC "sleeps" for longer periods, operating current decreases until the power-down quiescent current is reached. The MAX186 typically consumes 3µA in full power-down mode, and 38µA in fast power-down mode.

MAX186/187/188/189 POWER-DOWN CHARACTERISTICS



MAXIM

LOW POWER 12-BIT SAMPLING ADCs

- **5mA Max Continuous Current Consumption**
- **50µA Max Shutdown Current**
- **Internal Track/Hold**
- **Serial/Parallel Interface**
- **35µs Wake Up Time From Standby**

MAX190	MAX191
• Single +5V Supply Unipolar Operation	• +5V or ±5V Supplies Unipolar/Bipolar Operation
• 76kSPS	• 100kSPS

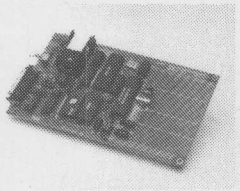
MAXIM

The MAX190/191 combine 12-bit A/D conversion with the capability for ultra-low power operation. With the power-down input, the converters can be disabled between conversions, consuming less current (20µA typ, 50µA max) than even low power integrating A/Ds. The MAX190/191 provide both serial and 8-bit parallel interfaces.

The MAX190 samples at up to 76kSPS, and accepts a unipolar signal while operating from a single 5V supply, while the MAX191 samples at 100kSPS, operates from 5V or ±5V supplies, and excepts either unipolar or bipolar signals.

MAX190 EVALUATION KIT

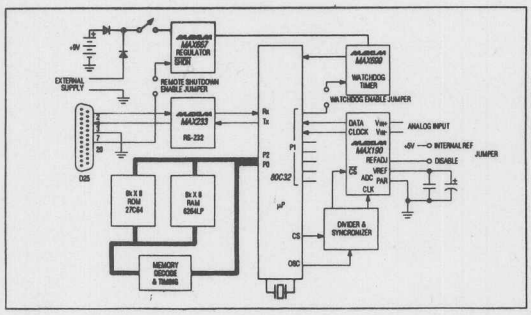
- MAX190 12-Bit 7.5µs + T/H + Ref ADC
- Microprocessor-Based Evaluation Circuit
- Proven Printed Circuit Board Layout
- Debugged Software Source Code
- Board Operates from a Single +6V to +10V Supply
- Interface to IBM-Compatible Computer through RS-232 Port



MAXIM

A complete evaluation board for the MAX190 includes an 80C31 microcontroller, ROM, RAM, software, and source code. Other ICs that complete the A/D prototyping system include a MAX667 low-dropout voltage regulator, and a MAX699 µP supervisor/reset IC. The entire board operates from a 9V battery.

MAX190 EV-KIT SYSTEM DIAGRAM



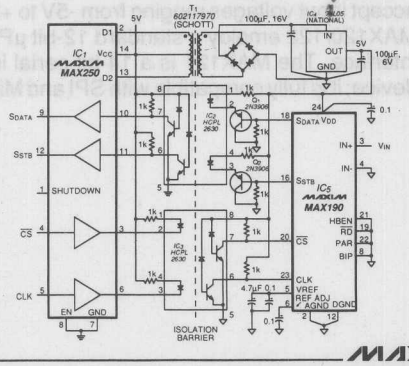
MAXIM

A remote data acquisition system (DAS) often requires some form of isolation to accommodate large ground potential differences. One solution isolates the analog signal from the rest of the circuit. A more practical and lower cost scheme isolates only the ADC. In this configuration, the MAX190 (with Track-and-Hold) is isolated by a transformer and two high-speed dual opto-couplers; it can withstand as much as 2500VDC for one minute.

The MAX250 drives the transformer to power the isolated side and converts opto-coupler levels to and from TTL. The MAX190's serial data outputs reduce the number of opto-couplers required. The interface is compatible with both SPI and MICROWIRE serial interface standards. The MAX190 offers 5V operation, a 0-to-5V input range, and an onboard voltage reference. Q1 and Q2 boost current drive to the optocouplers.

Note: the transformer shown in this circuit is also available from Newport Components Ltd. (phone number: 44 908 615 232) in the UK; the part number is 76250.

ISOLATED 12-BIT DATA ACQUISITION SYSTEM



MAXIM

MAXIM LOW POWER ADCs

PART	BITS	SAMPLE RATE	T/H	INT REF	INPUT CH	SHUT-DOWN CURRENT	INTER-FACE	EV KIT	COMMENTS
MAX132	18	16SPS	Not Needed	–	1	10µA	Serial	Yes	Logic outputs for mux control
MAX135	15	16SPS		–	1	10µA	Parallel	–	
MAX153	8	1MSPS	Yes	–	1	1µA	Parallel	Yes	Zero wake up time, +5V or ±5V supplies
MAX186	12	130kSPS	Yes	Yes	8	10µA	Serial	Yes	Auto logic shutdown, +5V or ±5V supplies
MAX187	12	130kSPS	Yes	Yes	1	10µA	Serial	–	Logic shutdown input, +5V or ±5V supplies
MAX188	12	130kSPS	Yes	–	8	10µA	Serial	–	Auto logic shutdown, +5V or ±5V supplies
MAX189	12	130kSPS	Yes	–	1	10µA	Serial	–	Auto logic shutdown, +5V or ±5V supplies
MAX190	12	76kSPS	Yes	Yes	1	50µA	Serial/ Parallel	Yes	Single +5V supply, 5mA max supply current, 35µs wakeup
MAX191	12	100kSPS	Yes	Yes	1	50µA	Serial/ Parallel	–	+5V or ±5V supplies, unipolar or bipolar input

MAXIM

HIGH SPEED 12- & 14-BIT DATA ACQUISITION

SPEED AND...

- **Low Cost (MAX120/121/122)**
- **Small Package with T/H & Ref. (MAX176)**
- **14 Bits (MAX168)**
- **Complete Data Acquisition System (MAX180/181)**

MAXIM

LOW-COST 500kSPS 12-BIT SAMPLING ADCs

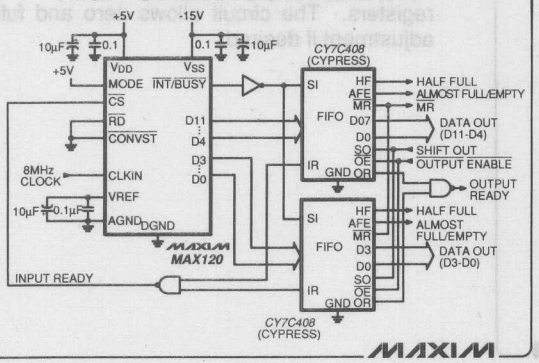
- **1.6µs Conversion and 350ns Acquisition**
- **Internal Track/Hold and Reference**
- **Low Noise (70dB SNR) and Distortion (-75dB THD)**
- **1/2LSB INL**
- **Low Power Dissipation: 210mW Typ.**
- **MAX120 Evaluation Kit Available**

	SPEED	INTERFACE
MAX120	500kSPS	Parallel
MAX121	400kSPS	Serial
MAX122	333kSPS	Parallel

MAXIM

The MAX120/121/122 ADCs include a 350ns acquisition time Track-and-Hold and a low-drift (±20ppm/°C max.) reference. Each accept input voltages ranging from -5V to +5V. The MAX120/122 employ a standard 12-bit µP parallel interface. The MAX121 is a 14-bit serial interface device; it is fully compatible with SPI and Microwire.

FIFO BUFFERS DATA FROM HIGH-SPEED CONVERTER



Two paralleled FIFOs are used to hold data output from a MAX120. The data is held until the microprocessor is free to store it in memory. Operated in continuous conversion mode, the MAX120 loads the FIFOs until one or both Input Ready (IR) outputs go low for an extended period of time, indicating the FIFO is full. (IR briefly goes low after each conversion result is loaded.) The consequent raising of the MAX120 Chip Select ($\overline{CS}$) input halts conversions. Since the FIFO shifts in parallel data on the rising edge of SI, the MAX120 Busy signal is inverted to ensure its data is valid when the signal at SI rises.

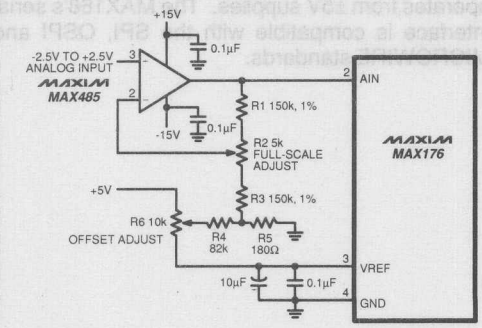
3.5µs 12-BIT SAMPLING ADC IN 8-PIN PACKAGE MAX176

- **250kSPS**
- **Serial Interface – SPI, QSPI, & Microwire Compatible**
- **400ns Acquisition Time Track/Hold**
- **±5V Input Voltage Range**
- **On-Chip Reference**
- **Low Power: 148mW**

MAXIM

The MAX176 A/D incorporates a Track-and-Hold and reference in an 8-pin package and performs conversions in under 3.5µs. The part's three-wire serial interface requires only a clock and conversion start signal to start a conversion. After a conversion has been initiated, data is transmitted serially. The serial interface is completely compatible with the SPI, QSPI, and Microwire serial interfaces standards.

ANALOG OFFSET AND GAIN ADJUST



MAXIM

Few precision A/Ds can be conveniently adjusted for zero and full-scale errors. In some cases trims are so awkward that the manufacturer recommends using op amp offset adjust pins to zero A/D errors. This approach not only suffers from limited trim range, but can actually add to errors by increasing the amplifier's temperature drift.

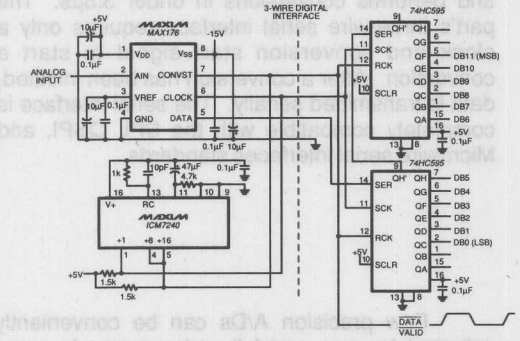
The circuit shown here, which is incorporated on the MAX176 evaluation board (next slide), is an effective way to add zero and gain adjustment to an A/D (or any analog signal). Offset and gain adjustments are independent of each other. The gain adjust range of this circuit is nominally ±3% while offset adjust is nominally ±18mV. These ranges are well beyond those needed to correct MAX176 full-scale and offset errors. An alternative to these adjustments is to correct offset and gain errors in software. Either of these techniques is appropriate whenever adjustment capability is not built into the A/D; devices such as the MAX180/181 include built-in adjustment circuitry.

- **Serial-to-Parallel Conversion for Easy Evaluation**
- **Pads for Optional Offset and Gain Adjust Circuitry**
- **PC Board and All Components Provided**

MAXIM

adjustment if desired.

MAX176 "QUICK LOOK" CIRCUIT

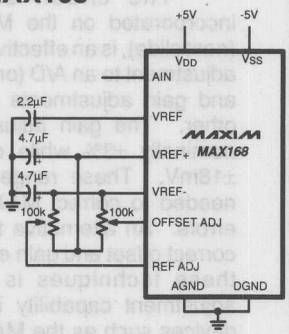


MAXIM

When breadbording the MAX176, it is sometimes easier to generate Conversion Start and Clock with a counter/timer chip than with pulse generators. The ICM7240 provides a Conversion Start pulse for every 16 clock cycles it generates. Due to the counter's limitations, the upper clock frequency limit is about 1MHz. Stray capacitive loading of the counter output must also be minimized so that the MAX176 minimum CONVST rise time spec is met.

14-BIT SAMPLING ADC MAX168

- **250kSPS**
- **Internal T/H**
- **Internal Reference**
- **Serial/Parallel Interface**
- **SPI,QSPI,& Microwire Compatible**
- **±5V Supplies**



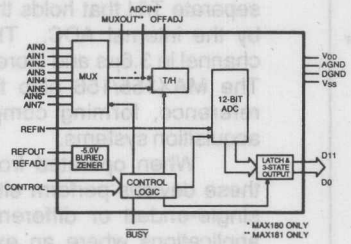
MAXIM

The MAX168 250kSPS 14-bit sampling ADC offers both serial and parallel interface capability, offset and reference adjustment inputs, and operates from ±5V supplies. The MAX168's serial interface is compatible with the SPI, QSPI and MICROWIRE standards.

SINGLE-CHIP 8-CH 12-BIT 100kSPS SYSTEM

MAX180/181 Replaces:

- AD574 12-Bit ADC
- DG508 Mux
- HA5330 Track-and-Hold
- Glue Logic
- Precision Resistors
- Bypass Capacitors for Multiple Chips

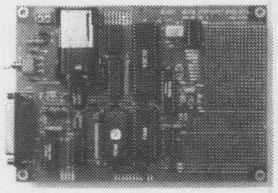


MAXIM

A complete data acquisition system on a chip eliminates the need to design one on a PC board. Interface problems like ground loops, noise coupling, and stray capacitance can be avoided because a number of analog and digital interconnects are eliminated. The MAX180 contains an 8-channel analog multiplexer, a wide-bandwidth track/hold, a 25ppm/°C voltage reference, and a 7.5µs A/D with a fast parallel 8- or 16-bit microprocessor interface. Each channel is µP-configurable for differential/single-ended and unipolar/bipolar input ranges. This data acquisition system is fully specified with both DC and dynamic testing.

MAX180 EVALUATION KIT

- 12-Bit, 8-Channel Data-Acquisition System
- Proven Printed Circuit Board Layout
- Operates from a Single +6V to +10V Supply

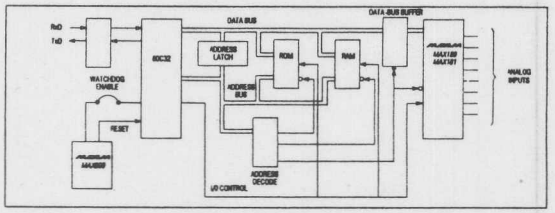


- Debugged Software Source Code
- Prototyping Area for the User's Signal Conditioning Circuits
- Interfaces to IBM-Compatible Computer through RS-232 Port

MAXIM

A complete single-chip 8-Channel 12-Bit data acquisition system gets even faster to design with a complete evaluation board. Included are an 80C31 microcontroller, ROM, RAM, software, and source code.

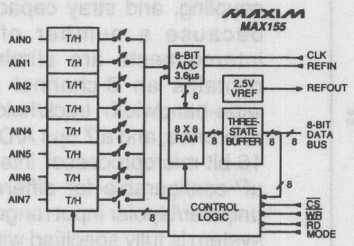
MAX180 EV-KIT SYSTEM DIAGRAM



MAXIM

HIGH SPEED ADC WITH 8 SIMULTANEOUS T/Hs

- 3.6µs Conversion Time per Channel
- On-Chip 8X8 Dual-Port RAM
- Internal 2.5V Reference
- +5V or ±5V Operation
- 8/4 Analog Input Channels (MAX155/156)
- Single-Ended or Differential Inputs



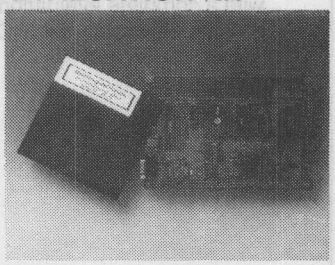
MAXIM

The MAX155/156 are high-speed, multi-channel 8-bit A/D Converters with simultaneous Track-and-Hold and 8 X 8 dual-port RAM. The MAX155 has 8 analog input channels, and the MAX156 includes 4. Each channel has a separate T/H that holds the signal for conversion by the internal ADC. The ADC converts each channel in 3.6µs and stores the result in the RAM. The MAX155/156 also feature a 2.5V on-chip reference, forming complete high-speed data acquisition systems.

When operated from a single 5V supply, these devices perform either unipolar or bipolar, single-ended or differential conversions. For applications where an extended input range or bipolar conversion about ground is important, an optional negative supply pin is provided.

MAX155 EVALUATION KIT

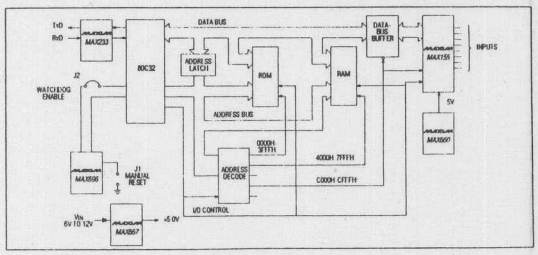
- Fully Functional 8-Channel, 8-Bit DAS
- 0V to 2.5V Unipolar or ±2.5V Bipolar Input Range
- Mixed Input Configurations are Possible



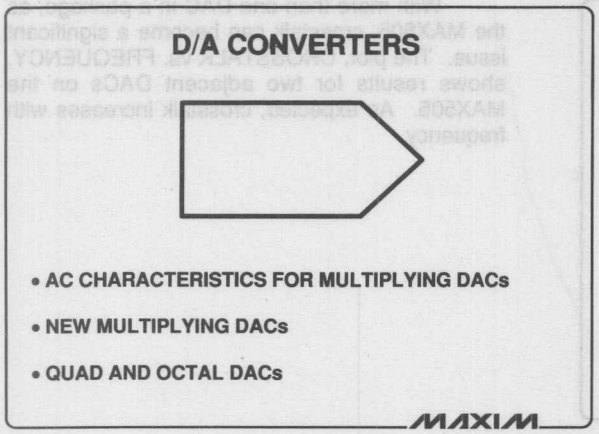
- EV Kit Operates from a Single Input Supply
- Software for IBM-Compatible Computers Included

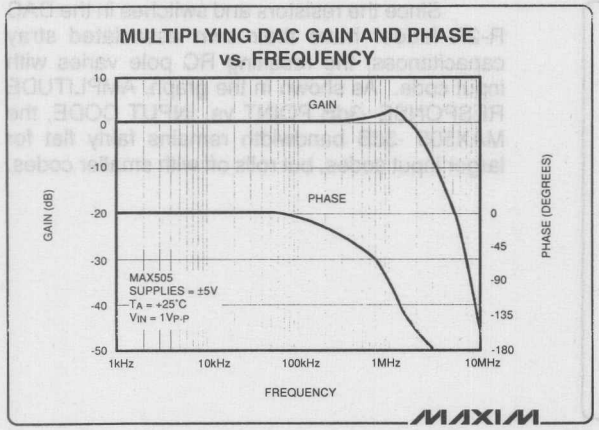
MAXIM

MAX155 EV-KIT SYSTEM DIAGRAM



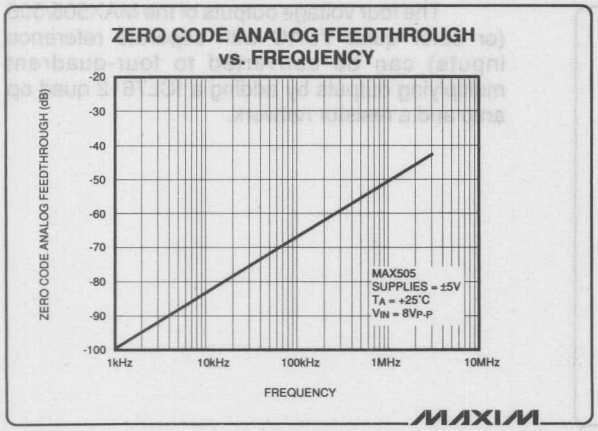
MAXIM



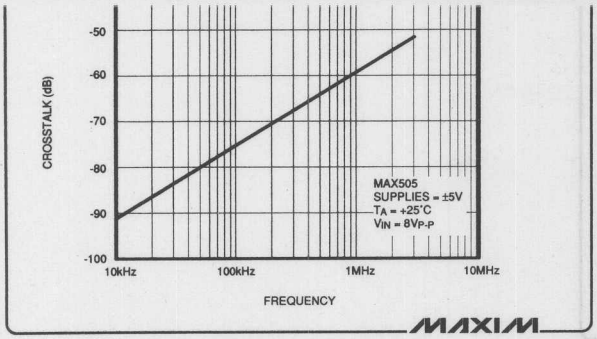


Dynamic Performance of Multiplying DACs

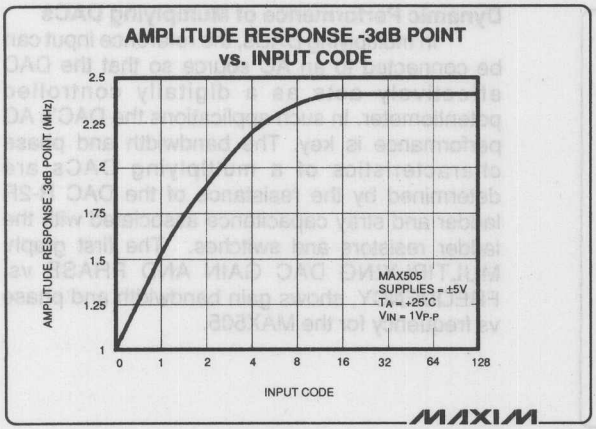
In multiplying DACs, the reference input can be connected to an AC source so that the DAC effectively acts as a digitally controlled potentiometer. In such applications the DAC's AC performance is key. The bandwidth and phase characteristics of a multiplying DACs are determined by the resistance of the DAC R-2R ladder and stray capacitance associated with the ladder resistors and switches. The first graph, MULTIPLYING DAC GAIN AND PHASE vs. FREQUENCY, shows gain bandwidth and phase vs frequency for the MAX505.



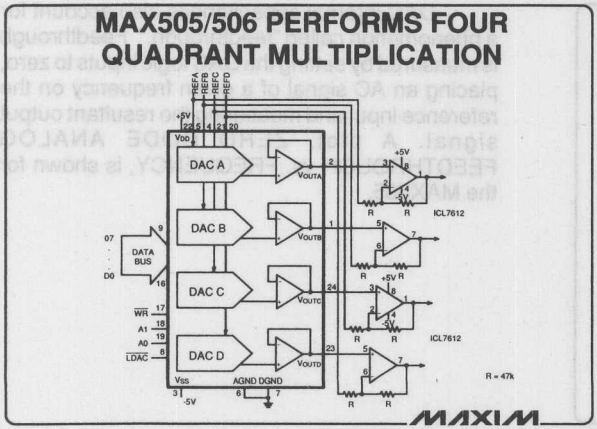
DAC internal capacitances also account for a phenomenon called "feedthrough." Feedthrough is measured by setting the DAC logic inputs to zero, placing an AC signal of a given frequency on the reference input and measuring the resultant output signal. A plot, ZERO CODE ANALOG FEEDTHROUGH vs. FREQUENCY, is shown for the MAX505.



MAX505. As expected, crosstalk increases with frequency.

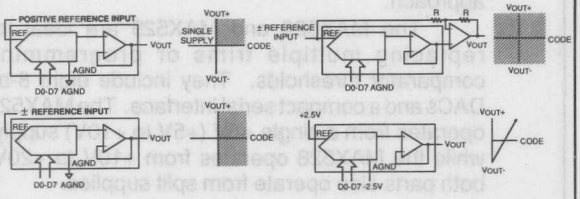


Since the resistors and switches in the DAC R-2R ladder have their own associated stray capacitances, the resulting RC pole varies with input code. As shown in the graph, AMPLITUDE RESPONSE -3dB POINT vs. INPUT CODE, the MAX505 -3dB bandwidth remains fairly flat for larger input codes, but rolls off with smaller codes.



The four voltage outputs of the MAX505/506 (or other quad VDAC with separate reference inputs) can be converted to four-quadrant multiplying outputs by adding a ICL7612 quad op amp and a resistor network.

MAX505/506 OPERATING CONFIGURATIONS



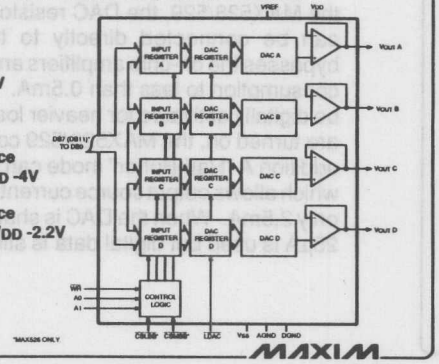
MAXIM

The MAX505/506 perform single quadrant multiplication when a single supply is used. Two quadrant multiplication is accomplished with a bipolar reference. The addition of an external amplifier allows the MAX505/506 to perform true four quadrant multiplication.

By applying +2.5V to the reference pin and -2.5V to the AGND pin, the DAC output can be made to range between +2.5V and -2.5V.

MAX526/527 QUAD 12-BIT VOLTAGE OUTPUT DAC

- **MAX526 +15V/-5V**
- **MAX527 ±5V**
- **MAX526 Reference Range: 2V to V_{DD} -4V**
- **MAX527 Reference Range: 1.2V to V_{DD} -2.2V**



MAXIM

Maxim supplies several Quad 12-bit DACs. They provide digital control of analog functions in applications ranging from gain control to auto-calibration.

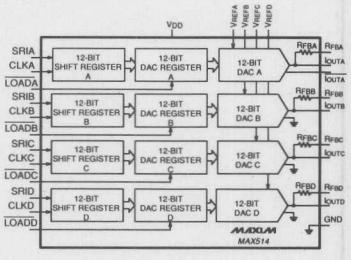
The MAX526/527 quad 12-bit voltage output DACs include precision output buffer amplifiers. Both devices feature double-buffered parallel interface logic with a 12-bit input register and 12-bit DAC register. Offset, gain and linearity are factory calibrated to provide 1LSB Total Unadjusted Error (TUE). The MAX526 operates from +15V and -5V, while the MAX527 is optimized for a single 5V supply.

The MAX514 is a Quad 12-bit current output multiplying DAC, featuring separate 3-wire serial interfaces. Each DAC has a 12-bit shift register to load serial data, and a DAC register to minimize digital noise feedthrough.

If desired, the clock and data lines of all four DACs can be paralled, with DAC selection controlled via the four Load pins.

MAX514 QUAD 12-BIT CURRENT OUTPUT DAC

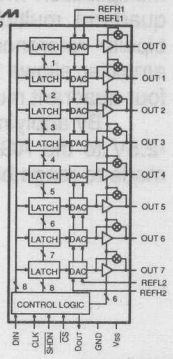
- **Four Quadrant**
- **Four Independent Serial D/As**
- **Bipolar Reference Range**



MAXIM

MAX528/529 OCTAL 8-BIT SERIAL DACs

- Single +5V or ±5V Supplies – MAX529
- 0 TO 2.5V Output Swing — MAX529, +5V Supply, Unbuffered Mode
- Serial Interface — SPI/Microwire Compatible
- Logic Power Down

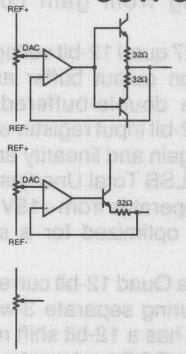


MAXIM

Mechanical trimpots can suffer from incorrect adjustment, changes due to time and mechanical vibration, and environmental extremes. A "Digital" pot allows adjustments to be done by software—a more reliable and lower cost approach.

The MAX528 and MAX529 are ideal for replacing multiple trims or programming comparator thresholds. They include eight 8-bit DACs and a compact serial interface. The MAX529 operates from a single +5V (+5V to +10V) supply, while the MAX528 operates from +10V to +20V; both parts also operate from split supplies.

MAX528/529 CONFIGURABLE OUTPUT STAGE



FULL BUFFER
Sources +5mA; sinks -2mA
Swings V_{DD} -3V to V_{SS} +1.5V (MAX528)
Swings V_{DD} -2.25V to V_{SS} (MAX529)

HALF BUFFER
Sources +5mA
Swings V_{DD} -3V to V_{SS} (MAX528)
Swings V_{DD} -2.25V to V_{SS} (MAX529)

UNBUFFERED
Swings V_{DD} -3V to V_{SS} (MAX528)
Swings V_{DD} -2.25V to V_{SS} (MAX529)
Output Z = 13k typ., 20k max.

MAXIM

When high-impedance loads are driven by the MAX528/529, the DAC resistor ladder outputs can be connected directly to the load. This bypasses the on-chip amplifiers and lowers current consumption to less than 0.5mA. The buffers can be digitally activated for heavier loads. If all buffers are turned on, the MAX528/529 consume 8mA. In addition A "Half-Buffer" mode can be programmed which allows output source currents, but consumes only 2.5mA. When the DAC is shut down, less than 25µA is used but digital data is still retained.

12-BIT SERIAL MULTIPLYING DAC IN 8-PIN SO MAX543



- 3-Wire Serial Interface
- Operates with +5V or +15V Supplies
- Low INL and DNL (±½LSB Max)

MAXIM

Maxim's smallest 12-bit DAC just got even smaller. The MAX543 is now available in an 8-pin SO package.

12-BIT VDAC WITH REFERENCE
MAX530/531

- **Four Quadrant Multiplication with No External Components**
- **+5V or ±5V Supplies**
- **INTERNAL REFERENCE**
- **SPI + Microwire Compatible Serial Interface (MAX531)**
- **2mW Power Consumption**

MAXIM

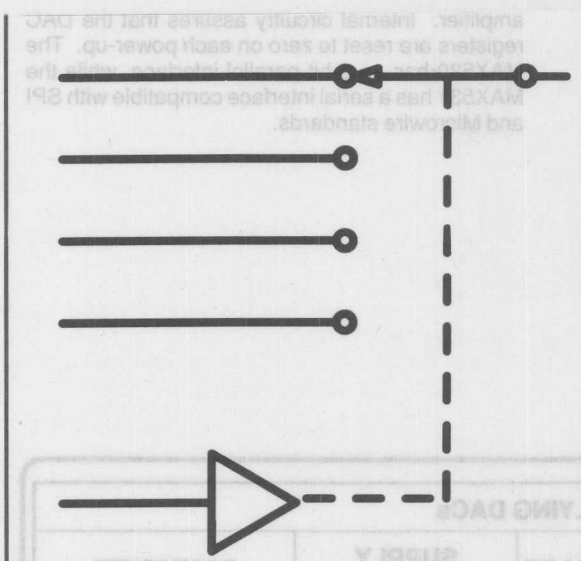
The MAX530/531 low power 12-bit voltage output DACs operate from single 5V or dual ±5V supplies. Power consumption is 2mW for single supply and 3mW for dual supplies. Included are a 2V reference and a precision output buffer amplifier. Internal circuitry assures that the DAC registers are reset to zero on each power-up. The MAX530 has an 8-bit parallel interface, while the MAX531 has a serial interface compatible with SPI and Microwire standards.

NEW MULTIPLYING DACs

PART NUMBER	BITS	SETTLING TIME (µs)	NUMBER OF DACs	INTERFACE	SUPPLY VOLTAGE	COMMENTS
MAX501	12	5 (MAX)	1	µP/12	±12V/±15V	Four quadrant
MAX502	12	5 (MAX)	1	µP/8	±12V or ±15V	
MAX505	8	8 (TYP)	4	µP/8	+5V or ±5V	Four reference inputs
MAX506	8	8 (TYP)	4	µP/8	+5V or ±5V	Common reference input
MAX507	12	5 (MAX)	1	µP/12	+12V, +15V or ±15V	Internal reference
MAX508	12	5 (MAX)	1	µP/8	+12V, +15V or ±15V	Internal reference
MAX514	12	1 (MAX)	4	SERIAL	+5V	Separate serial interface for each DAC Current Output
MAX526	12	3 (TYP)	4	µP/8	+15V/-5V	Two reference inputs each shared by two DACs
MAX527	12	3 (TYP)	4	µP/8	±5V	
MAX528	8	1 (TYP)	8	SERIAL	+12V or +12V/-5V	
MAX529	8	1 (TYP)	8	SERIAL	+5V or ±5V	DAC register set to zero on power up
MAX530	12	25 (TYP)	1	µP/8	+5V or ±5V	Low Power, Internal Reference
MAX531	12	25 (TYP)	1	SERIAL	+5V or ±5V	Low power, Internal Reference

MAXIM

Maxim offers many multiplying DACs with the right combination of features to fit a wide variety of applications.



- Selecting Switches and Muxes
- Glitch-Free Operation
- Understanding Charge Injection
- Fault-Protected Switches

MAXIM

HOW TO SELECT SWITCHES AND MULTIPLEXERS

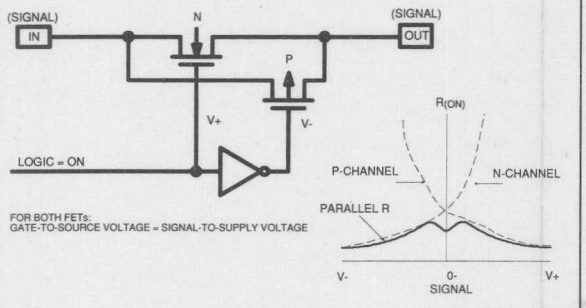
- $R_{DS(ON)}$
- Charge Injection
- Leakage Currents
- Fault Protection
- Power Supply Considerations

MAXIM

Selecting a CMOS analog switch can be a straightforward process when you know the rules and how to apply them. The most important things are: switch on resistance [$R_{DS(ON)}$], charge injection, leakage currents, fault protection, and power supply considerations. Each of these is covered below, with emphasis on using the manufacturers' specifications, and how to get around them when they seem to be inadequate for your job.

If a switch or multiplexer data sheet seems to not have the specification that is vital to your design, it is smart to ask if the switch was intended for your application, or if there is a better way to do the job.

$R_{DS(ON)}$ – HOW IT WORKS

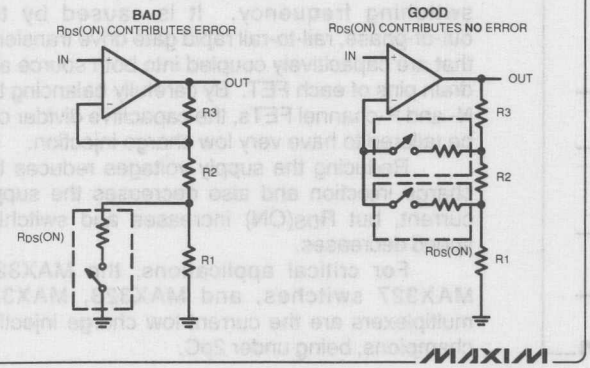


MAXIM

CMOS switches are constructed by paralleling N-channel and P-channel MOSFET transistors and driving their gates out of phase with rail-to-rail logic signals to turn them on or off. The P-channel source is connected to the N-channel drain and vice-versa, which insures that at least one of the FETs will be on regardless of the signal voltage. The signal-to-supply voltages are the gate-to-source voltages for both FETs, so as the signal voltage changes, the $R_{DS(ON)}$s change slightly. The effect is magnified as the supply voltage is lowered. [$R_{DS(ON)}$ increases with lower supply voltages because the gate drive voltage is effectively lowered.] The $R_{DS(ON)}$ resistance has a poor temperature coefficient.

If the signal voltage goes beyond the supply voltage, the switch will conduct at an ever increasing rate to the supply rail, possibly damaging the switch. The switch leakage currents (on or off) flow almost entirely to the supply rails.

AVOIDING $R_{DS(ON)}$ PROBLEMS

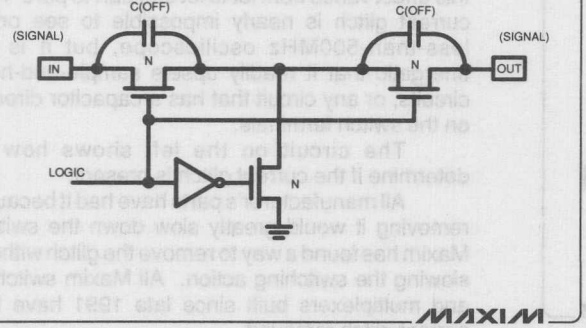


MAXIM

There is almost always a way around the $R_{DS(ON)}$ temperature coefficient problem. In this example, the gain of a non-inverting op-amp is set to two values by opening and closing a switch under logic control. The rule is simple: place the switch in a path that does not conduct significant amounts of current.

The example circuit requires placing the switch in the op-amp input and adding a second switch, but the improvement in performance is dramatic. The "Good" circuit gain is almost entirely determined by the resistors R1-R3, without consideration of $R_{DS(ON)}$ or its temperature coefficient. One benefit is that a very high on resistance switch can be used.

AVOIDING C(OFF) PROBLEMS



MAXIM

At RF frequencies, the problem is not only turning the switch on, but turning it off. Capacitance between the source and drain couples high frequencies directly through an "off" switch. The solution shown at the left is used by the MAX310 and MAX311 multiplexers and the MAX453/4/5/6 MUX/amplifiers.

This scheme employs a "T" configuration of N-channel FETs. When the switch is on, both series FETs conduct and the shunt FET is off. When it is off, energy that is coupled through the off channel FETs is shunted to ground through the 3rd FET. This improves high frequency off isolation dramatically.

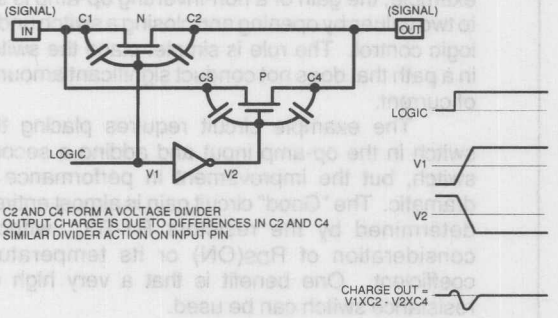
RF SWITCHES USING "T" SWITCHES

- **MAX310 8-Channel MUX**
- **MAX311 Differential 4-Channel MUX**
- **MAX453 2-Channel MUX & 75Ω Driver**
- **MAX454 4-Channel MUX & 75Ω Driver**
- **MAX455 8-Channel MUX & 75Ω Driver**
- **MAX456 8X8 Crosspoint Switch & 400Ω Driver**

MAXIM

These CMOS RF switches Use the "T" architecture to get good off isolation See the Video Products section for a more complete discussion of both CMOS and biploar high frequency products.

CHARGE INJECTION



C2 AND C4 FORM A VOLTAGE DIVIDER
OUTPUT CHARGE IS DUE TO DIFFERENCES IN C2 AND C4
SIMILAR DIVIDER ACTION ON INPUT PIN

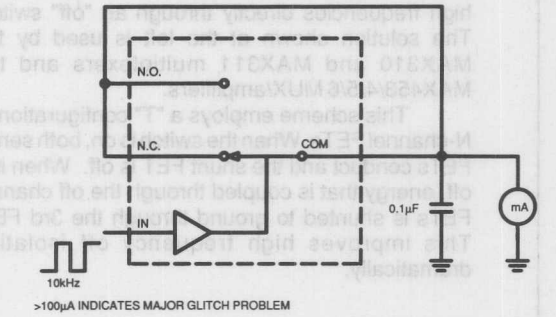
MAXIM

Charge Injection is the small amount of energy transferred through the CMOS switch terminals each time the switch changes state. It manifests itself as extra current flowing in the circuit that should not be there, and it is proportional to the switching frequency. It is caused by the out-of-phase, rail-to-rail rapid gate drive transients that are capacitively coupled into both source and drain pins of each FET. By carefully balancing the N- and P-channel FETs, the capacitive divider can be tailored to have very low charge injection.

Reducing the supply voltages reduces the charge injection and also decreases the supply current, but $R_{DS(ON)}$ increases and switching speed decreases.

For critical applications, the MAX326, MAX327 switches, and MAX328, MAX329 multiplexers are the current low charge injection champions, being under 2pC.

FINDING CURRENT GLITCHES



>100µA INDICATES MAJOR GLITCH PROBLEM

MAXIM

Current glitches are often mistaken for charge injection because they also produce energy in the switching circuit. The cause is due to a timing overlap in the gate drivers, and the effect is a very narrow (<5 nanoseconds!) pulse that extends nearly to the negative supply rail. The severity of this effect varies from lot to lot and part to part. This current glitch is nearly impossible to see on a less-than-500MHz oscilloscope, but it is so energetic that it readily upsets sample-and-hold circuits, or any circuit that has a capacitor directly on the switch terminals.

The circuit on the left shows how to determine if the current glitch is present.

All manufacturer's parts have had it because removing it would greatly slow down the switch. Maxim has found a way to remove the glitch without slowing the switching action. All Maxim switches and multiplexers built since late 1991 have the current glitch removed.

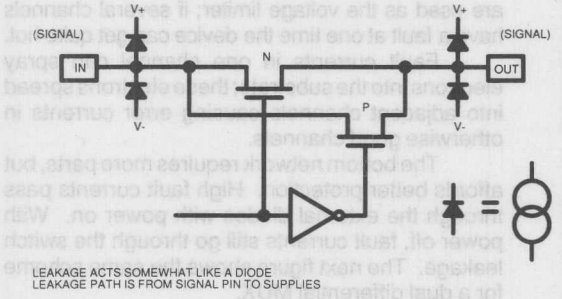
THE DG400 SWITCH FAMILIY

- Low $R_{DS(ON)}$ – 35Ω
- Fast – t_{ON} < 150ns
- Low Charge Injection – 1pC
- Break-Before-Make Timing
- Second Sourced!

DG401	DG403	DG405	DG406
DG407	DG408	DG409	DG411
DG412	DG413	DG417	DG418
DG419	DG421	DG423	DG425
DG441	DG442	DG444	DG445

MAXIM

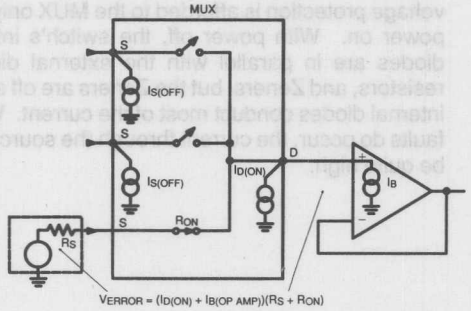
LEAKAGE CURRENTS



LEAKAGE ACTS SOMEWHAT LIKE A DIODE
LEAKAGE PATH IS FROM SIGNAL PIN TO SUPPLIES

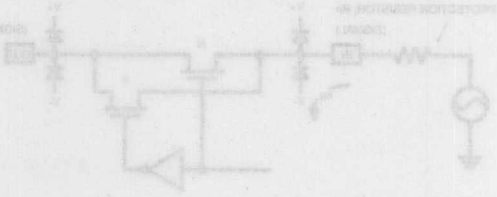
MAXIM

WHAT ON AND OFF LEAKAGES MEAN



MAXIM

The DG400 family of switches and multiplexes that have nearly everything, including a second source.



Switches and MUXs have leakage that acts somewhat like reverse-biased diodes connected to both supply rails. Switch leakage currents are principally to the supply rails, not to the other switch terminal. These currents increase as temperature increases.

There is no way to guess which polarity the leakage current will flow, likewise there is no way to match them. Notice that since there are two paths in series, the only current flowing out the switch terminal is the difference between the currents in any pair.

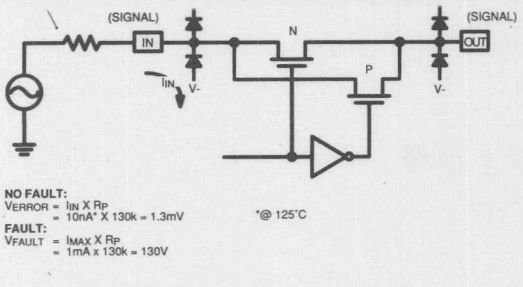
For many signal routing applications, CMOS switches perform as nearly "ideal" elements. However, as accuracy requirements increase, leakage currents contribute increasingly to measurement error. The error is the product of switch leakage current and the signal source resistance (including switch on-resistance, $R_{DS}ON$). Leakage specs are divided into several types. In a multiplexer these are:

$I_{S(OFF)}$: Leakage in or out of an **OFF input** channel. This does not affect output error unless the OFF channel is connected to an ON-channel on a different multiplexer.

$I_{D(OFF)}$: Leakage in or out of an **OFF output** (The mux ENABLE input must be low for the output to be off). This contributes to error if the mux output is connected to other mux outputs (for more channels).

$I_{D(ON)}$: Leakage into the **ON mux output** when a channel is selected. This is the largest contributor to error except where mux outputs are paralleled. Since the channel is on, this spec includes both the input and output leakage.

Low leakage improves accuracy by reducing the voltage error across source impedances and on-resistances. It also enables higher-valued input resisitors to provide improved input protection without adding to error.

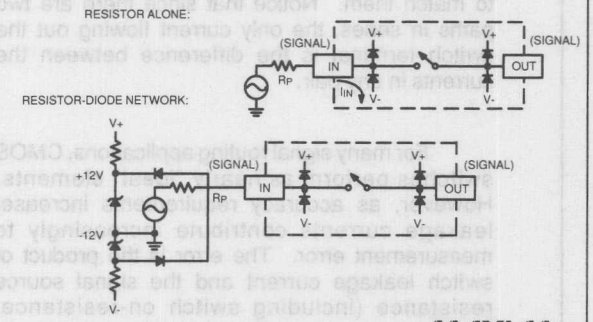


protect it against high voltages. Here, for example, we use a 130kΩ resistor to get 130V protection and yet the 10nA leakage current (maximum over temperature) of the MAX328 produces only a 1.3mV error.

The fault current, I_{MAX}, should be less than the maximum switch rating (usually 10mA) and less than the source's current tolerance. In this example, 1mA. is used.

Also, don't forget to calculate the maximum power in the resistor, in this case, 130mW.

DISCRETE COMPONENTS FOR FAULT PROTECTION

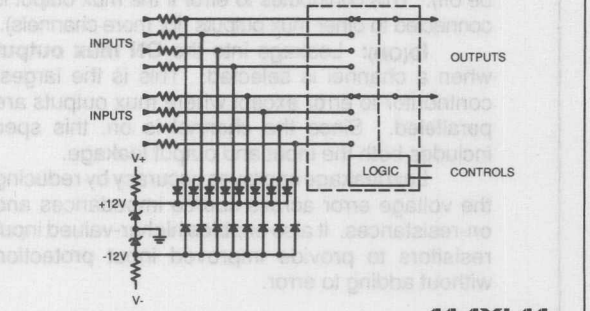


Fault voltages can be prevented from causing damage with several schemes. Resistor protection alone is used at the top. The switch's internal diodes are used as the voltage limiter; if several channels have a fault at one time the device can get quite hot.

Fault currents in one channel can spray electrons into the substrate; these electrons spread into adjacent channels causing error currents in otherwise good channels.

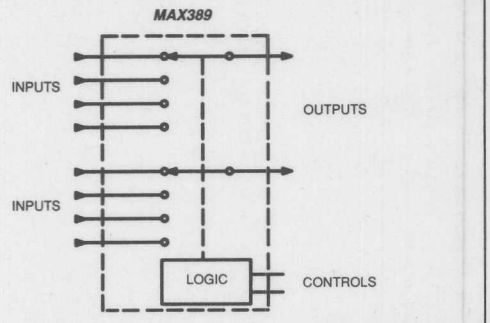
The bottom network requires more parts, but affords better protection. High fault currents pass through the external diodes with power on. With power off, fault currents still go through the switch leakage. The next figure shows the same scheme for a dual differential MUX.

DISCRETE DIODE-RESISTOR FAULT PROTECTION FOR 4 CHANNEL DIFFERENTIAL MUX



Here is a typical discrete protection network for a differential 4-channel MUX. It requires 10 resistors, 2 Zeners, and 8 low-leakage diodes. Despite the large number of components, very high voltage protection is afforded to the MUX only with power on. With power off, the switch's internal diodes are in parallel with the external diodes, resistors, and Zeners, but the Zeners are off so the internal diodes conduct most of the current. When faults do occur, the current through the source can be quite high.

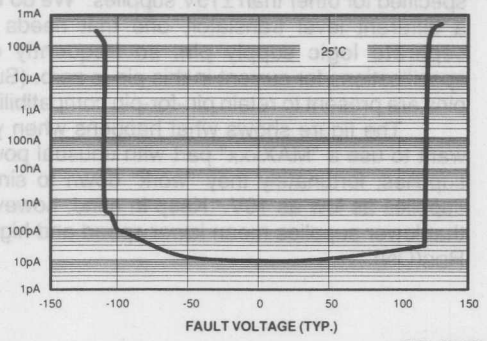
100 VOLT FAULT PROTECTED DIFFERENTIAL 4-CHANNEL MUX



MAXIM

The contrast between the fault protected MUXs and the discrete solution is obvious, but the real benefits are the better specifications that few designers have the patience to duplicate discretely.

FAULT CURRENT vs FAULT VOLTAGE MAX378, MAX379, MAX388, MAX389

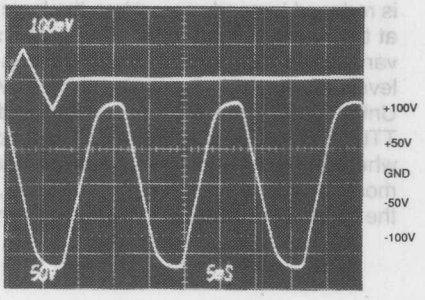


MAXIM

Here is a plot of the typical fault current through Maxim's fault protected MUXs. The data shows the current through any input or output pin with power off. There is no significant loading of the source, no fault current, no spraying of electrons into adjacent channels, no pushing of current into either supply rail, and no heating.

With ±15V power applied, the curves are nearly identical except the current starts rising 15V lower. This reflects the surprising fact that protection is better with power off. These devices are guaranteed to handle ±100V with power off, ±50V with ±15V supplies.

FAULT-INDUCED OTHER CHANNEL INTERFERENCE



MAXIM

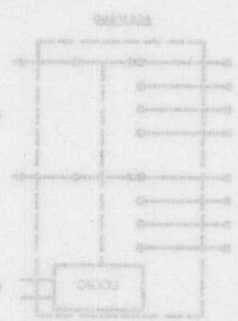
A further benefit of fault protected multiplexers is that when faults do occur in one channel, there is no significant energy induced into other channels. This is due partly to the fact that there is no significant fault current in the switch. Such current tends to spray electrons all over the substrate in a conventional MUX, causing all manner of havoc with adjacent channel signals.

The scope photo shows a 200mV peak-to-peak single triangle wave followed by a long flat period. This waveform is on one input and the output; it is the selected channel on an 8-channel MUX. The source impedance is 1000Ω. The lower channel shows a 230V peak-to-peak signal connected to another channel. By holding the page sideways you can discern some feedthrough on the flat portion of the 200mV signal, but the effect is very slight. The 230V signal was left on over night and there was no discernible temperature rise in the MUX. Note, however, that ±115V is beyond the specifications, i.e., don't count on it. Also, the ±115V is peak-to-peak, not RMS.

FAULT PROTECTION SUMMARY

- **Protects Switch**
- **Does Not Load Source**
- **Protects Downstream Device**
- **Protects Channel Data**
- **No Temperature Rise**
- **Output Polarity Same as Input, No "Glitch"**
- **All Channels Can Have Faults at Once**
- **Same Benefits with Power On Or Off**

MAXIM



POWER SUPPLY CONSIDERATIONS

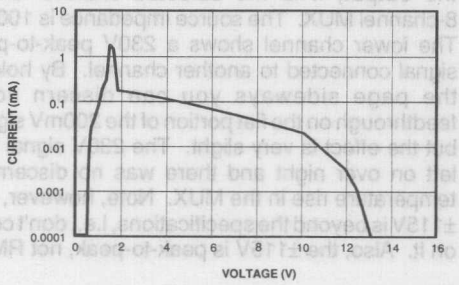
- **All Maxim "MAXxxx" Switches Operate with Single Supplies**
- **Logic Levels Can Swing Analog Rail-to-Rail**
- **Analog Signal Range Rail-to-Rail – Except Fault Protected Devices**
- **All Are Both CMOS and TTL Compatible**

MAXIM

Maxim's second source CMOS switches and Multiplexers operate similarly to the original manufacturer's part, and generally are not specified for other than ±15V supplies. We do use a different level translator, one that needs no separate logic supply pin, so frequently our specifications for current in this pin is zero. (Such pins are present to retain pin-for-pin compatibility.)

The figure shows what happens when you want to use a "MAXxxx" part with unusual power supplies; fortunately they "work" down to single supplies as low as 10V. Keep in mind, however, that lower supplies mean lower speed and higher $R_{DS(ON)}$.

MAX327
ISUPPLY vs. SWITCH CONTROL



MAXIM

A N-channel or P-Channel MOSFET switch draws no power from the power supply. All the power is consumed by the digital interface (the level translator between logic and analog), and even that is reduced to nearly zero when the logic levels are at the analog supply rails. The graph shows the variation in supply current with various static DC levels on the logic input pin, using 15V supplies. Unfortunately, the greatest current is drawn with TTL level inputs (0.8 and 2.4V) around the area where the level translator is operating in its linear mode. If the logic is rail-to-rail CMOS, however, the supply current drops to vanishingly small levels.

MAXIM QUALITY

- **New Product Release Procedure**
- **Reliability Qualification Tests**
- **Continual Reliability Monitoring**
- **Reliability History**
- **Production Stress Screening**
- **Lot Traceability**
- **Available Quality/Reliability Literature**

MAXIM

Maxim maintains that Quality is not a negotiable attribute but is a commitment that the supplier maintains with its customers. It is a trust that must be preserved. Maxim accomplishes this by using various controls and systems. These ensure the consistent production of reliable products.

The 5 major controls and systems are:

- New Product Release Procedures
- Reliability Qualification
- Continual Reliability Monitoring
- Production Stress Screening
- Lot Traceability

NEW PRODUCT RELEASE PROCEDURE

- **Test Program Conforms to Data Sheet**
- **Life Test (192 hours at 135˚C, biased, 80 units)**
- **Pressure Pot (96 hours at 121˚C, 100% RH, unbiased, 45 units)**
- **ESD (Every pin measured per MIL STD 3015.7. Design target is ±2000V.)**
- **Latch-Up Sensitivity (Every pin required to withstand 50mA injected current)**
- **Noise Performance (Where Applicable)**

MAXIM

New products are the most prone to exhibit anomalies because of the inexperience of both ourselves and our customers. Speeding up the learning process is brought about by various self checks and sanity checks made prior to production release. Product-by-product reliability testing serves as a supplement to the full-blown Reliability Qualifications done on each process and package family.

RELIABILITY QUALIFICATION REQUIREMENTS FOR ICs IN PLASTIC PACKAGES

STRESS TEST NAME	CONDITION	SAMPLING PLAN SS/Acc	SAMPLING PLAN OR LTPD	END POINTS
Life Test, Dynamic Dynamic preferable	125°C/1000Hrs or 150°C/192Hrs	77/1	5%	Electrical
85/85	85°C/85% RH 1000Hrs (Note 1)	77/1	5%	Electrical
Pressure Pot	121°C/15psig 168Hrs (Note 1)	77/0		Electrical
HAST	129°C/85% RH 100Hrs (Note 1)	25/1		Electrical
Temperature Cycle	-65°C to 150°C 1000X	77/1	5%	Electrical
High Temperature Storage	150°C/1000Hrs	77/1	5%	Electrical
ESD	Human body model 2000V	5/0		Electrical
Latch-Up	±50mA, CMOS only	5/0		Electrical
Solder Shock	260°C/5sec solder dip	15/0	15%	Electrical
Resist to Soldering Heat	300°C/10sec	15/0	15%	Electrical
Salt Test	Thermal shock 10X + pressure pot 30Hrs (Note 2)	Information		Electrical
Wire Bond Pull	On line 5 grams min	45/0	5%	
Die Shear	On line	5/0		
Physical Dimensions	per drawing	15/0	15%	Visual
Lead Fatigue	>3 90 degree bends	15/0 leads	15%	Visual
Tensil Strength	8oz weight/30sec	15/0 leads	15%	Visual
Solderability	min 4Hrs steam aging	15/0 leads	15%	Visual
Resistance to Solvents		15/0	15%	Visual
Adhesion of Lead Finish		15/0 leads	15%	Visual
Salt Atmosphere		15/0	15%	Visual
External Visual		15/0	15%	Visual
Plating Thickness	200µ-inch min	10/0		

Notes:
1. Preconditioning is required for moisture related tests which include 85/85, Pressure pot, HAST test.
   Preconditioning test condition is:
   Temperature cycle -65°C to 150°C for 10X, followed by 260°C solder dip/10sec for 3 times.
2. Salt test preconditioning and procedure-
   a. Solder Dip 260°C/10sec
   b. Solder Iron 300°C/10sec
   c. Thermal Shock in salt solutions (20% weight) 0°C to 100°C for 12 cycles. Parts should remain at each temperature for 10 minutes.
   d. Pressure pot 30Hrs.

MAXIM

The complete list of Qualification Tests and test conditions are shown.

Note that most of the endpoint measurements are taken against the datasheet test limits. Data from these tests are available for customer review.

RELIABILITY MONITORING

- **Humidity Test (Weekly)**
  - **3 lots per week per pkg family per assembly facility.**
  - **96Hrs pressure pot, sample size = 45.**
- **Life Test (Weekly)**
  - **3 lots per week per process per fab.**
  - **192Hrs Life Test, sample size = 80.**
- **Process/Mask Change Characterization**
  - **192Hrs Life Test**
  - **ESD**
  - **Latch-up**
  - **Product Parametric Characterization**
  - **Yield Verification**

MAXIM

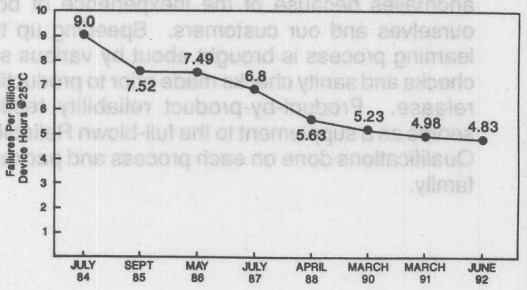
Continual Reliability Monitoring is done for two reasons: to check that the quality of existing products and processes remains stable, and to verify that product or process changes preserve or enhance quality.

First, random samples are pulled from production lots weekly for Humidity (Pressure Pot) and Life Test. The sampling plans and sample sizes provide sufficient visibility into our fabrication and assembly processes for defect detection. This also allows Maxim to react in a timely manner to initiate corrective measures prior to any customer involvement.

Second, every new mask change or process iteration is qualified through a shortened qualification process. This process comprises:

- 192 hour life testing
- ESD verification
- Latch-up susceptibility verification
- Product parameter characterization
- Yield verification

MAXIM'S RELIABILITY HISTORY (FAILURES IN TIME)



MAXIM

The results of this activity can be simply viewed from the Reliability History graph. Maxim has maintained a constant downward trend through continuous improvement programs focused on the major failure modes.

MAJOR COMPONENTS FOR MAXIM'S PRODUCTION STRESS SCREENING

100% Temperature Cycling
(-65°C to +150°C, 10 cycles)

100% Hot Temperature Test
(70°C Commercial
85°C Extended/Industrial)

100% Burn-in
(On DIP package only for processes not yet achieving less than 300ppm infant mortality)

100% Q.A. Sampling of Every Lot
(AQL = 0.1%, based on MIL-STD-150D)

MAXIM

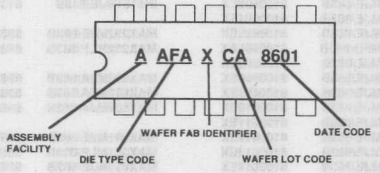
Maxim's production stress screening serves to eliminate time zero defects as well as to reduce the number of infant mortality failures. Electrical test is used as the primary vehicle for defect detection. Typically this is done at high temperature and then at room temperature. The elevated temperature test augments the 100% temperature cycling screen the product goes through during assembly. Temperature cycling helps identify devices with an intermittent failure, e.g. a loose bond-wire or a cracked die.

Maxim has also used burn-in extensively to help weed out infant mortality failures. The need for burn-in has been reduced with the improvements to our fabrication processes. Maxim's inherent failure rate is under 300ppm. At this rate the advantages of burn-in are greatly diminished.

QA sample testing is performed to a 0.1% AQL (Acceptable Quality Level) criterion using an accept on zero sampling plan. This type of QA sampling is applied to both electrical and mechanical attributes of our product.

LOT TRACEABILITY

All Maxim Products are Fully Traceable from Individual Device Back to Starting Material



MAXIM

Maxim has an effective traceability scheme that facilitates post-sales material management. This scheme shown allows for traceability to the raw silicon from which the product was fabricated. If a customer has a problem with a particular lot, he can call Maxim with the identifying ID printed on the back of each IC, and our Applications or Failure Analysis staff can then match this number with the corresponding archive sample. This sample can then be measured according to the customer's usage, and the reported problem evaluated. Valuable time is saved by avoiding the need for transporting correlation samples. The backmark ID code can also assist in the unlikely event of a product recall.

RELIABILITY LITERATURE

General Reliability Report **RR-1F**
Summarizes Maxim's Life Test monitoring program and product history.

Metal Gate CMOS Reliability Report **QR-1A**
Comprehensive reliability focus on the product and processes maintained at Maxim's own Fab.

Surface Mount Reliability Report **RR-2A**
Summarizes the humidity performance of our SOIC products through various thermal/moisture tests.

Quality Assurance Manual **QM-1A**
Outlines all major systems used in the control of Maxim's manufacturing.

Product Specific Reliability Reports . . . . . **200 Available**
Summarizes the reliability data specific to any individual product.

Quarterly Reliability Updates Available
Summarizes all reliability monitor data taken for the past quarter. Includes failure analysis of any defects detected.

MAXIM

Further explanation of these systems is contained in Maxim's Reliability and Quality literature. All of the general reports are maintained at both our sales and representatives offices. Detailed individual product reliability reports can be ordered through any Maxim sales office.

HI-REL MILITARY PRODUCT AVAILABILITY

- Standard Military Drawing (SMD)
  - Factory Inventory
- MIL-STD-883B, Rev. C Compliant NON-JAN
  - Supported by /883 Military Device Data Sheets
  - Factory Inventory
- "/HR" Hi-Reliability Processing/Screening Flow
  - Screening Flow Using MIL-STD-883B, Methods 5004/5005
  - Any Military Temperature Range Product Available in This Flow
  - Some Inventory of Popular Types
  - Alternative to Fully Qualified /883 Material

MAXIM

MAXIM QUALIFIED MILITARY DISTRIBUTORS

- Arrow Electronics
  Brookhaven, New York
- Bell Industries
  Dayton, Ohio
- Pioneer Electronics
  Woodbury, L.I., New York Branch
- Hall-Mark Electronics
  Dallas, Texas

MAXIM

883 COMPLIANT PRODUCTS

ADCs
*MAX150/MX7820
MAX154/MX7824
MAX158/MX7828
MAX160/MX7574
MAX161/MX7581
MAX170
MAX172/MX7572
MX574
MX674A
MX7575
MX7672

DACs
MAX543
MX7224
MX7225
MX7226
MX7228
MX7520/30/33
MX7521
MX7523
MX7524
MX7528
MX7537
MX7541/41A
MX7542
MX7543
MX7545A
MX7548
MX7547
MX7628

SWITCHES
DG200A
DG201A/202
DG300/1/2/3A
DG304/5/6/7A
DG308A/309
DG381/84/87/90A
HI201
IH5040-47
IH5048-51
IH5140-47
IH5341
IH5352
MAX331/332
MAX333
*DG401-403
*DG411-413
*DG417-419
*DG441/442

MULTIPLEXERS
MAX310/311
*MAX328/329
MAX358/359
*MAX368/369
*MAX378/379
*MAX388/389
*MX7501/2/3
MX7506/7
DG506A/507A
DG508A/509A
DG528/529
IH6108/6208
*DG406/407
*DG408/409

POWER SUPPLY
DC-DC
MAX634
MAX638
MAX680

LINEAR REGULATOR
MAX663
MAX664
MAX666

MOS DRIVERS
MAX626
MAX627
MAX628
TSC426
TSC427
TSC428
ICL7667

REFERENCES
MX580
MX581
MX584
REF01
REF02
MAX674
MAX675

INTERFACE
MAX231
MAX232
MAX233
MAX238
*MAX250
*MAX251

OP-AMP
OP07
ICL7642
ICL7650
*MAX452/453

SUPERVISORY
MAX690
MAX691
MAX692
MAX693
MAX694
MAX695
MAX696
MAX697
MAX1232

*AVAILABLE DEC. 1992

MAXIM

DESC APPROVED DEVICES TO STANDARD MILITARY DRAWING (SMDs) CURRENTY AVAILABLE

MAXIM P/N	SMD P/N	MAXIM P/N	SMD P/N
IH5040MJE/883B	8100601EX	IH5149MJE/883B	8100620EX
IH5041MJE/883B	8100602EX	IH5150MJE/883B	8100621EX
IH5042MJE/883B	8100603EX	IH5151MJE/883B	8100622EX
IH5043MJE/883B	8100604EX		
IH5044MJE/883B	8100605EX	MAX232MJE/883B	5962-8987701EX
IH5045MFD/883B	8100606AX	MAX232MLP/883B	5962-89877012X
IH5045MJE/883B	8100606EX		
IH5047MJE/883B	8100608EX	MAX690MJA/883B	5962-9071201MPX
IH5140MJE/883B	8100609EX	MAX692MJA/883B	5962-9071202MPX
IH5141MJE/883B	8100610EX	MAX694MJA/883B	5962-9071203MPX
IH5142MJE/883B	8100611EX		
IH5143MJE/883B	8100612EX	MAX691MJE/883B	5962-9071101MEX
IH5144MJE/883B	8100613EX	MAX691MLP/883B	5962-9071101M2X
IH5145MJE/883B	8100614EX	MAX693MJE/883B	5962-9071102MEX
IH5147MJE/883B	8100616EX	MAX693MLP/883B	5962-9071102M2X
IH5148MJE/883B	8100619EX	MAX695MJE/883B	5962-9071103MEX

MAXIM

DESC APPROVED DEVICES TO STANDARD MILITARY DRAWING (SMDs) CURRENTY AVAILABLE (CONT)

MAXIM P/N	SMD P/N	MAXIM P/N	SMD P/N
MAX8211MTV/883B	5962-9081101MGX	MX7528UQ/883B	5962-8770103RX
MAX8211MJA/883B	5962-9081101MPX		
MAX8212MTV/883B	5962-9081102MGX	MX7541ASQ/883B	5962-8948101VX
MAX8212MJA/883B	5962-9081102MPX	MX7541ASE/883B	5962-89481012X
MX7226TQ/883B	5962-8780201RX	MX7541ATQ/883B	5962-8948102VX
MX7226TE/883B	5962-87802012X	MX7541ATE/883B	5962-89481022X
MX7524SQ/883B	5962-8770001EX	MX7572SQ12/883B	5962-8759101LX
MX7524SE/883B	5962-87700012X	MX7572TQ12/883B	5962-8759102LX
MX7524TQ/883B	5962-8770002EX	MX7572SQ05/883B	5962-8759104LX
MX7524TE/883B	5962-87700022X	MX7572TQ05/883B	5962-8759105LX
MX7524UQ/883B	5962-8770003EX		
MX7524TE/883B	5962-87700032X	MX7574TQ/883B	5962-8961603VX
		MX7574TE/883B	5962-89616032X
MX7528SQ/883B	5962-8770101RX	MX7574SQ/883B	5962-8961604VX
MX7528TQ/883B	5962-8770102RX	MX7574SE/883B	5962-89616042X

MAXIM

DESC APPROVED DEVICES TO STANDARD MILITARY DRAWING (SMDs) CURRENTY AVAILABLE (CONT)

MAXIM P/N	SMD P/N	MAXIM P/N	SMD P/N
MX7820UQ/883B	5962-8865001RX	REF01AJ/883B	5962-8958101GX
MX7820UE/883B	5962-88650012X	REF01AZ/883B	5962-8958101PX
MX7820TQ/883B	5962-8865002RX		
MX7820TE/883B	5962-88650022X	REF02AJ/883B	8551401GX
		REF02AZ/883B	8551401PX
MX7824TQ/883B	5962-8876401LX		
MX7824UQ/883B	5962-8876402LX	TSC426MJA/883B	5962-8850301PX
		TSC426MNP/883B	5962-8503012X
MX7828TQ/883B	5962-8876403XX	TSC427MJA/883B	5962-8850302PX
MX7828UQ/883B	5962-8876404XX	TSC427MNP/883B	5962-88503022X
		TSC428MJA/883B	5962-8850303PX
REF01J/883B	5962-8958102GX	TSC428MNP/883B	5962-88503032X
REF01Z/883B	5962-8958102PX		

MAXIM

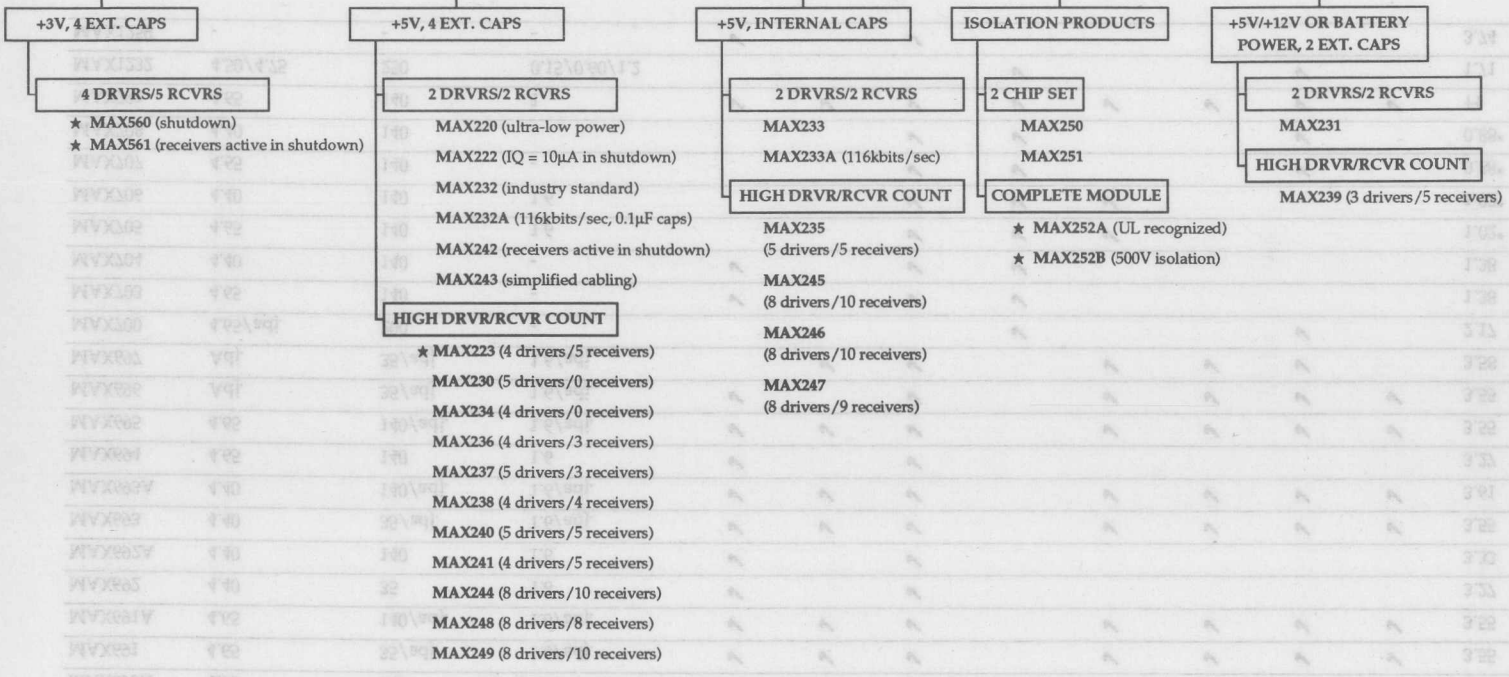
Part Number	Power Supply (V)	# of RS-232 Drivers	# of RS-232 Receivers	# of Ext. Caps	Nominal Cap. Value (µF)	Shutdown & 3-State	Supply Current (mA max)	Guaranteed Data Rate (kbits/sec max)	Features	Pri 10(($)
MAX220	+5	2	2	4	4.7/10	No	2	20	Ultra low-power, industry-standard pinout	2.2
MAX222	+5	2	2	4	0.1	Yes	10	116	MAX232A with shutdown	2.2
MAX223	+5	4	5	4	1.0	Yes	15	20	+5V IBM PC serial port w/ receivers active in shutdown	3.2
MAX230 (MAX200)	+5	5	0	4	1.0	Yes	15 (20)	20	5 drivers with shutdown	3.2
MAX231	+5 and +7.5 to +13.2	2	2	2	1.0	No	1/5	20	Standard +5/+12V or battery supplies; same functions as MAX232	1.9
MAX232 (MAX202)	+5	2	2	4	1.0	No	10 (15)	20	Industry standard	1.9
MAX232A	+5	2	2	4	0.1	No	10	116	Higher slew rate, small caps	2.2
MAX233 (MAX203)	+5	2	2	0	-	No	10 (15)	20	No external caps	3.6
MAX233A	+5	2	2	0	-	No	10	116	No external caps, high slew rate	4.2
MAX234 (MAX204)	+5	4	0	4	1.0 (0.1)	No	15 (20)	20	Replaces 1488	3.1
MAX235 (MAX205)	+5	5	5	0	-	Yes	15 (20)	20	No external caps	6.3
MAX236 (MAX206)	+5	4	3	4	1.0 (0.1)	Yes	15 (20)	20	Shutdown, three-state	3.2
MAX237 (MAX207)	+5	5	3	4	1.0 (0.1)	No	15 (20)	20	Complements IBM PC serial port	3.2
MAX238 (MAX208)	+5	4	4	4	1.0 (0.1)	No	15 (20)	20	Replaces 1488 and 1489	3.2
MAX239 (MAX209)	+5 and +7.5 to +13.2	3	5	2	1.0 (0.1)	No	1/15 (20)	20	Standard +5/+12V or battery supplies; single package solution for IBM PC serial port	3.2
MAX240	+5	5	5	4	1.0	Yes	15	20	DIP or flatpak package	5.1
MAX241 (MAX211)	+5	4	5	4	1.0 (0.1)	Yes	15 (20)	20	Complete IBM PC serial port	3.2
MAX242	+5	2	2	4	0.1	Yes	10	116	Separate shutdown and enable	2.2
MAX243	+5	2	2	4	0.1	No	10	116	Open-line detection simplifies cabling	2.2
MAX244	+5	8	10	4	1.0	No	25	64	High slew rate	7.(
MAX245	+5	8	10	0	-	Yes	25	64	High slew rate, int. caps, two shutdown modes	12
MAX246	+5	8	10	0	-	Yes	25	64	High slew rate, int. caps, three shutdown modes	12
MAX247	+5	8	9	0	-	Yes	25	64	High slew rate, int. caps, nine operating modes	12
MAX248	+5	8	8	4	1.0	Yes	25	64	High slew rate, selective half-chip enables	7.(
MAX249	+5	6	10	4	1.0	Yes	25	64	MAX248 with 2 complete IBM PC serial ports	7.(
MAX560	+3	4	5	4	1.0	Yes	8	20	+3V MAX561 + receivers active in shutdown	3.2
MAX561	+3	4	5	4	1.0	Yes	8	20	+3V Complete IBM PC serial port	3.2
RS-232 ISOLATION PRODUCTS										
MAX250	+5	2	2	-	-	Yes	-	20	Isolated RS-232 chipset	3.2
MAX251	+5	2	2	-	-	Yes	-	20	Isolated RS-232 chipset	3.2
MAX252A	+5	2	2	0	-	Yes	90	9.6	UL recognized, 1500V isolation	45
MAX252B	+5	2	2	0	-	Yes	90	9.6	Economical 500V isolation	27

† Prices provided are for design guidance and are FOB USA. International prices will differ due to local duties, taxes, and exchange rates.

Part Number	Output	Display Format	Input Format	Input Formula	Number of Annunciators	LCD or LED	Features	Price† 1000-up ($)
ICM7211	4 digit	Hexadecimal or code B	Multiplexed or microprocessor interface	4-bits data	No independent annunciators	LCD	Muxed version, 4 digit strobes; Interfaced version, 2 digit address	2.42
ICM7212	4 digit	Hexadecimal or code B	Multiplexed or microprocessor interface	4-bits data	No independent annunciators	LED	Muxed version, 4 digit strobes; Interfaced version, 2 digit address	2.05
MAX7219	8 digit	7 segment or no decode	Serial entry	8-bits data 8-bits address	No independent annunciators	LED	True 3-wire serial interface	3.99
MAX7220	8 digit	7 segment or no decode	Parallel entry	8-bits data	No independent annunciators	LED	20ns access time	††
MAX7231	8 digit	Hexadecimal or code B	Parallel entry	4-bits data 2-bits annunciator 3-bit address	16	LCD	"A" & "B" versions, both annunciators on COM3; "C" version, annunciators on COM1 & COM3	4.50
ICM7218/ ICM7228	8 digit	Hexadecimal or no decode	Parallel entry	6-bits data	No independent annunciators	LED	"A" version drives common anode display; "B" version drives common cathode display	4.33
MAX7232	10 digit	Hexadecimal or code B	Serial entry	4-bits data 2-bits annunciator 4-bit address	20	LCD	"A" & "B" versions, both annunciators on COM3; "C" version, annunciators on COM1 & COM3	4.37
MAX7233	4 char.	64 character ASCII	Parallel entry	6-bits ASCII data 2-bit address	No independent annunciators	LCD	"A" version, half-width numbers; "B" version, full-width numbers	4.06
MAX7234	5 char.	64 character ASCII	Serial entry	6-bits ASCII data 3-bit address	No independent annunciators	LCD	"A" version, half-width numbers; "B" version, full-width numbers	4.51

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†† Future product – contact factory for pricing and availability.

RS-232 LINE DRIVERS/RECEIVERS



★ New product since the publication of the 1990 Short Form Product Guide.

Part Number	Nominal Reset Threshold (V)	Minimum Reset Pulse Width (ms)	Nominal Watchdog Timeout Period (sec)	Backup-Battery Switch	$\overline{CE}$ Write Protect	Power-Fail Comparator	Manual Reset Input	Watchdog Output	Low-Line Output	Active-High Reset	Battery-On Output	Price† 1000-up ($)
MAX690	4.65	35	1.6	✔		✔						3.27
MAX690A	4.65	140	1.6	✔		✔						3.33
MAX691	4.65	35/adj.	1.6/adj.	✔	✔	✔		✔	✔	✔	✔	3.55
MAX691A	4.65	140/adj.	1.6/adj.	✔	✔	✔		✔	✔	✔	✔	3.55
MAX692	4.40	35	1.6	✔		✔						3.27
MAX692A	4.40	140	1.6	✔		✔						3.33
MAX693	4.40	35/adj.	1.6/adj.	✔	✔	✔		✔	✔	✔	✔	3.55
MAX693A	4.40	140/adj.	1.6/adj.	✔	✔	✔		✔	✔	✔	✔	3.61
MAX694	4.65	140	1.6	✔		✔						3.27
MAX695	4.65	140/adj.	1.6/adj.	✔	✔	✔		✔	✔	✔	✔	3.55
MAX696	Adj.	35/adj	1.6/adj.	✔		✔		✔	✔	✔	✔	3.55
MAX697	Adj.	35/adj.	1.6/adj.		✔	✔		✔	✔	✔		3.58
MAX700	4.65/adj.	200	-				✔			✔		2.17
MAX703	4.65	140	-	✔		✔	✔					1.38
MAX704	4.40	140	-	✔		✔	✔					1.38
MAX705	4.65	140	1.6			✔	✔	✔				1.02*
MAX706	4.40	140	1.6			✔	✔	✔				1.02*
MAX707	4.65	140	-			✔	✔			✔		0.88*
MAX708	4.40	140	-			✔	✔			✔		0.88*
MAX791	4.65	140	1	✔	✔	✔	✔	✔	✔	✔	✔	††
MAX1232	4.50/4.75	250	0.15/0.60/1.2				✔			✔		1.71
MAX1259	-	-	-	✔		✔						3.74

* 25,000 pc. price, factory direct

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†† Future product – contact factory for pricing and availability.

µP SUPERVISORY CIRCUITS

FIVE FUNCTION 16-PIN

MAX691* (4.65V reset)

★ MAX691A

MAX693* (4.4V reset)

★ MAX693A

MAX695* (200ms reset pulse width)

SIX FUNCTION 16-PIN

MAX791 (2nd generation part)

FOUR FUNCTION 16-PIN

MAX696 (adj. reset threshold)

MAX697 (adj. reset threshold)

FOUR FUNCTION 8-PIN

MAX690* (4.65 reset)

★ MAX690A

MAX692* (4.4V reset)

★ MAX692A

MAX694* (200ms reset pulse width)

★ MAX703

★ MAX704

RESET AND WATCHDOG

★ MAX705

★ MAX706

MAX1232 (improved DS1232)

RESET ONLY

MAX700

RESET AND POWER FAIL

★ MAX707

★ MAX708

UNDER/OVERVOLTAG DETECTORS

SINGLE VOLTAGE DETECTORS

MAX8211 (noninverting)

MAX8212 (inverting)

DUAL VOLTAGE DETECTORS

ICL7665

* Not recommended for new designs.

★ New product since the publication of the 1990 Short Form Product Guide.

Part Number	Input Voltage Range (V)	Output Voltage (V)	Quiescent Supply Current (mA) max (typ)	Package Options*	Temp. Range**	Features	Price† 1000-up ($)
STEP-UP SWITCHING REGULATORS (PFM)							
MAX4193	2.4 to 16.5	$V_{OUT} > V_{IN}$	0.200 (0.090)	DIP, SO	C, E, M	Improved RC4193 2nd source	1.74
MAX630	2.0 to 16.5	$V_{OUT} > V_{IN}$	0.125 (0.070)	DIP, SO	C, E, M	Improved RC4193 2nd source	2.88
MAX631	1.5 to 5.6	+5, adj.	0.4 (0.135)	DIP, SO	C, E, M	Only 2 external components	2.56
MAX632	1.5 to 12.6	+12, adj.	2.0 (0.5)	DIP, SO	C, E, M	Only 2 external components	2.56
MAX633	1.5 to 15.6	+15, adj.	2.5 (0.75)	DIP, SO	C, E, M	Only 2 external components	2.56
MAX654	1.15 to 5.6	+5	(0.08)	DIP, SO	C, E, M	Optimized for 1 cell, evaluation kit available	3.35
MAX655	1.5 to 5.6	+5	(0.04)	DIP, SO	C, E, M	Optimized for 2 cells, evaluation kit available	3.35
MAX656	1.15 to 5.6	+5	(0.08)	DIP, SO	C, E, M	Drives external MOSFET	3.35
MAX657	1.15 to 3.6	+3	(0.08)	DIP, SO	C, E, M	Optimized for 1 cell, evaluation kit available	3.35
MAX658	1.5 to 5.6	+5	(0.04)	DIP, SO	C, E, M	Drives external MOSFET	3.35
STEP-UP SWITCHING REGULATORS (PWM)							
MAX731	1.8 to 5.25	+5	4 (2)	DIP, SO	C, E, M	Evaluation kit available	3.20
MAX732	4.0 to 9.0	+12	3 (1.7)	DIP, SO	C, E, M	Internal power MOSFET, ±4% output voltage tolerance, flash EEPROM programming power supply, 200mA output	2.66
MAX733	4.0 to 12.0	+15	3 (1.7)	DIP, SO	C, E, M	125mA output, evaluation kit available	3.23
MAX734	4.0 to 9.3	+12	3 (1.7)	DIP, SO	C, E, M	Flash-memory programer evaluation kit available	††
MAX751	1.8 to 5.25	+5	4 (2)	DIP, SO	C, E, M	Evaluation kit available	††
MAX752	1.8 to 16	Adj.	3 (1.7)	DIP, SO	C, E, M	Evaluation kit available	3.20
STEP-DOWN SWITCHING REGULATORS (PFM)							
MAX638	2.6 to 16.5	+5, adj.	0.6 (0.135)	DIP, SO	C, E, M	Only 3 external components	2.56
MAX639	4.0 to 11.0	+5, adj.	0.2 (0.1)	DIP, SO	C, E, M	>90% efficiencies over wide range (2mA to 225mA), DIP and SO evaluation kit available	2.96
STEP-DOWN SWITCHING REGULATORS (PWM)							
MAX730	5.2 to 11.0	+5	3 (1.7)	DIP, SO	C, E, M	300mA output, 90% efficiencies, DIP and SO evaluation kit available	3.09
MAX738	6.0 to 16.0	+5	3 (1.7)	DIP, SO	C, E, M	750mA output, >85% efficiencies, DIP and SO evaluation kit available	3.23
MAX750	4.0 to 11.0	Adj.	3 (1.7)	DIP, SO	C, E, M	1.5W output, 90% efficiencies, DIP and SO evaluation kit available	2.92
MAX758	4.0 to 16	Adj.	3 (1.7)	DIP, SO	C, E, M	3.75W output, >85% efficiencies, DIP and SO evaluation kit available	3.23

–Continued on the next page–

* Package Options: DIP = Dual-In-Line Package, SO = Small Outline, TO-99 = Can

** Temperature Ranges: C = 0°C to +70°C, I = -25°C to +85°C, E = -40°C to +85°C, M = -55°C to +125°C

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†† Future product - contact factory for pricing and availability.

DC/DC Converters (continued)

Part Number	Input Voltage Range (V)	Output Voltage (V)	Quiescent Supply Current (mA) max (typ)	Package Options*	Temp. Range**	Features	Price† 1000-up ($)
INVERTING SWITCHING REGULATORS (PFM)							
MAX4391	4.0 to 16.5	up to -20	0.25 (0.09)	DIP, SO	C, E, M	Improved RC4391 2nd source	2.09
MAX634	2.3 to 16.5	up to -20	0.15 (0.07)	DIP, SO	C, E, M	Improved RC4391 2nd source	2.61
MAX635	2.3 to 16.5	-5, adj.	0.15 (0.08)	DIP, SO	C, E, M	Only 3 external components	2.56
MAX636	2.3 to 16.5	-12, adj.	0.15 (0.08)	DIP, SO	C, E, M	Only 3 external components	2.56
MAX637	2.3 to 16.5	-15, adj.	10 (0.5)	DIP, SO	C, E, M	Only 3 external components	2.56
MAX650	-54 to -42	+5	0.15 (0.07)	DIP, SO	C, E, M	Telecom applications	3.50
INVERTING SWITCHING REGULATORS (PWM)							
MAX735	4.0 to 6.2	-5	3 (1.6)	DIP, SO	C, E, M	200mA output, 85% efficiencies	2.55
MAX736	4.0 to 8.6	-12	6 (4.2)	DIP, SO	C, E, M	>80% efficiencies, evaluation kit available	2.95
MAX737	4.0 to 5.5	-15	9 (6.1)	DIP, SO	C, E, M	>80% efficiencies, evaluation kit available	2.95
MAX739	4.0 to 16.0	-5	1.7 (3.5)	DIP, SO	C, E, M	300mA output, 80% efficiencies	2.95
MAX755	4.0 to 11.0	Adj.	3 (1.6)	DIP, SO	C, E, M	>80% efficiencies	††
MAX759	4.0 to 11.0	Adj.	2.2 (4.0)	DIP, SO	C, E, M	1.5W output, LCD driver, 80% efficiencies	2.95
DUAL OUTPUT SWITCHING REGULATORS (PWM)							
MAX742	4.2 to 10.0	±12, ±15	15 (8)	DIP, SO	C, E, M	Drives external MOSFETs, 30W output	3.91
MAX743	4.2 to 6.0	±12, ±15	30 (20)	DIP, SO	C, E, M	Internal power MOSFETs, evaluation kit and production kit available, 3W output	4.49
SWITCHING REGULATOR CONTROLLERS							
MAX641	1.5 to 5.6	+5, adj.	0.4 (0.135)	DIP, SO	C, E, M	PFM controller	2.87
MAX642	1.5 to 12.6	+12, adj.	2.0 (0.5)	DIP, SO	C, E, M	PFM controller	2.87
MAX643	1.5 to 15.6	+15, adj.	2.5 (0.75)	DIP, SO	C, E, M	PFM controller	2.87
MAX741U	2.7 to 15.5	+5, +12, +15, adj.	3.5 (1.6)	DIP, SO, SSOP	C, E, M	PWM step-up controller	††
MAX741D	2.7 to 15.5	+5 adj.	4.0 (2.8)	DIP, SO, SSOP	C, E, M	PWM step-down controller	††
MAX741N	2.7 to 15.5	-5, -12, -15, adj.	4.0 (2.2)	DIP, SO, SSOP	C, E, M	PWM inverting controller	††
CHARGE-PUMP CONVERTERS—UNREGULATED							
MAX660	1.5 to 5.5	+2 x V_{IN}, -V_{IN}	1.0 (0.6)	DIP, SO	C, E, M	I_{OUT} = 100mA	2.95
MAX680	2.0 to 6.0	± 2 x V_{IN}	2 (1)	DIP, SO	C, E, M		1.62
MAX681	2.0 to 6.0	± 2 x V_{IN}	2 (1)	DIP	C, E	No external components (internal caps)	4.64
ICL7660	1.5 to 10	-V_{IN}	0.175 (0.110)	DIP, SO, TO-99	C, E, M		1.09
ICL7662	4.5 to 20	-V_{IN}	0.6 (0.25)	DIP, SO, TO-99	C		1.76
Si7661	4.5 to 20	-V_{IN}	2 (0.3)	DIP, SO, TO-99	C		1.94
CHARGE-PUMP CONVERTERS—REGULATED HIGH-SIDE POWER SUPPLIES							
MAX622	3.5 to 16.5	V_{IN} + 11V	0.5 (0.07)	DIP, SO	C, E	3 external capacitors	1.99
MAX623	3.5 to 16.5	V_{IN} + 11V	0.5 (0.07)	DIP	C, E	No external capacitors	3.95

* Package Options: DIP = Dual-In-Line Package, SO = Small Outline, TO-99 = Can

** Temperature Ranges: C = 0°C to +70°C, I = -25°C to +85°C, E = -40°C to +85°C, M = -55°C to +125°C

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Power Management Supplies

Part Number	Input Voltage Range (V)	Linear Output Voltage (V)	DC-DC Output Voltages (V)	Quiescent Supply Current Temp. Max Range (mA)	Features	Price† 1000-up ($)
MAX714	5.05 to 11	2 at +5V lines	-5 to -26 adj. LCD driver	0.2 per C, E, M enabled output line	Independent shutdowns, backup-battery switchover, RESET and power-fail warning outputs	6.80
MAX715	5.05 to 11	3 at +5V lines	-5 adj., -5 to -26 adj., +12 or +15 adj.	0.2 per C, E, M, enabled output line	PC layout and parts list available	9.32
MAX716	5.05 to 11	4 at +5V lines	-5 adj., -5 to -26 adj., +12 or +15 adj.	0.2 per C, E, M, enabled output line	Independent shutdowns, backup-battery switchover, RESET and power-fail warning outputs, evaluation kit available	9.54

MOSFET Drivers

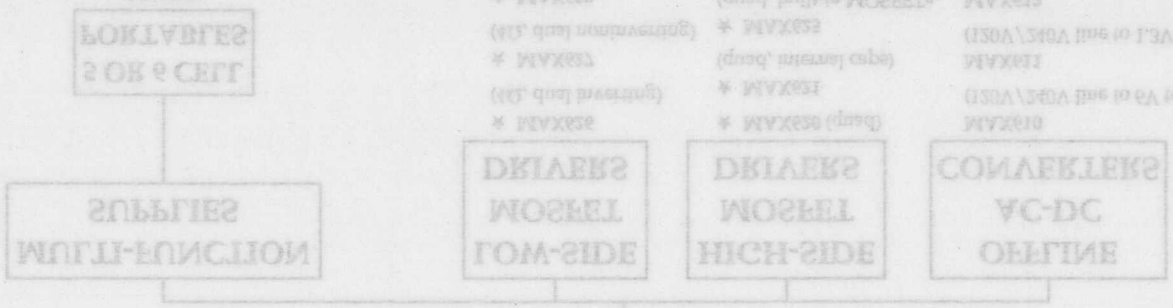
Part Number	Output Resistance (Ω) max (typ)	Rise/Fall T_A = +25°C (ns max)	Rise Time Over Temp. (ns max)	Fall Time Over Temp. (ns max)	Supply Voltage (V)	Package Options*	Temp. Range**	Features	Price† 1000-up ($)
MAX4426/7/8	10 (4)	30	40	40	4.5 to 18	DIP, SO	C, E, M	Dual inverting/dual noninverting/dual combo	1.61
MAX626/7/8	15 (4)	30	40	40	4.5 to 18	DIP, SO	C, E, M	Dual inverting/dual noninverting/dual combo	1.57
TSC426/7/8	15 (10)	30	60	40	4.5 to 18	DIP, SO	C, E, M	Dual inverting/dual noninverting/dual combo	1.06
ICL7667	12 (8)	30	40	40	4.5 to 15	DIP, SO, TO -99	C, E, M	Dual inverting	1.12

High-Side MOSFET Drivers

Part Number	Supply Voltage Range (V)	Quiescent Supply Current (mA) max (typ)	Switching Frequency (kHz)	Package Options*	Temp. Range**	Features	Price† 1000-up ($)
MAX620	4.5 to 16.5	0.5 (0.070)	70	DIP, SO	C, E	Quad high-side driver, V_{CC}+11V output	3.91
MAX621	4.5 to 16.5	0.5 (0.070)	70	DIP	C, E	Quad high-side driver, V_{CC}+11V output, internal capacitors	5.82
MAX625	4.5 to 16.5	0.5 (0.070)	70	DIP	C, E	Quad high-side switch, 4 internal 0.2Ω N-channel MOSFETs, internal capacitors	9.98

* Package Options: DIP = Dual-In-Line Package, SO = Small Outline, TO-99 = Can
** Temperature Ranges: C = 0°C to +70°C, I = -25°C to +85°C, E = -40°C to +85°C, M = -55°C to +125°C
† Prices provided are for design guidance and are FOB USA. International prices will differ due to local duties, taxes, and exchange rates.
†† Future product - contact factory for pricing and availability.

Part Number	Input Voltage Range (V)	Output Voltage (V)	Dropout Voltage	Quiescent Current (µA) max (typ)	Output-Voltage Accuracy	Shutdown	Package Options*	Temp. Range**
AC-DC REGULATORS								
MAX610	110/240VAC	Fixed +5 or +1.3 to +9	N/A	150 (70)	±4%	No	DIP	C
MAX611	110/240VAC	Fixed +5	N/A	150 (70)	±4%	No	DIP	C
MAX612	110/220VAC	Fixed +5 or +1.3 to +9	N/A	150 (70)	±4%	No	DIP	C
DC LINEAR REGULATORS - POSITIVE OUTPUT								
MAX663	+2 to +16.5	Fixed +5 or +1.3 to +15	0.9V at 40mA	12 (6)	±5%	Yes	DIP, SO	C, E, M
MAX666	+2 to +16.5	Fixed +5 or +1.3 to +15	0.9V at 40mA	12 (6)	±5%	Yes	DIP, SO	C, E, M
MAX667	+3.5 to +16.5	Fixed +5 or +1.3 to +15	0.15V at 200mA	25 (12)	±5%	Yes	DIP, SO	C, E, M
ICL7663	+1.5 to +16	+1.3 to +15	0.9V at 40mA	10 (4)	±8%	Yes	DIP, SO, TO-99	C, E, I, M
ICL7663A	+2.0 to +16	+1.3 to +15	0.9V at 40mA	10 (4)	±1%	Yes	DIP, SO, TO-99	C, E, I, M
ICL7663B	+1.5 to +16	+1.3 to +15	0.9V at 40mA	10 (4)	±8%	Yes	DIP, SO, TO-99	C, E, I, M
DC LINEAR REGULATORS - NEGATIVE OUTPUT								
MAX664	-2 to -16.5	Fixed -5 or -1.3 to -15	0.5V at 40mA	12 (6)	±5%	Yes	DIP, SO	C, E, M
ICL7664	-2 to -16	-1.3 to -15	0.4V at 30mA	10 (3.5)	±5%	Yes	DIP, SO, TO-99	C, I, M
ICL7664A	-2 to -16	-1.3 to -15	0.4V at 30mA	10 (3.5)	±1%	Yes	DIP, SO, TO-99	C, I, M



* Package Options: DIP = Dual-In-Line Package, SO = Small Outline, TO-99 = Can
** Temperature Ranges: C = 0°C to +70°C, I = -25°C to +85°C, E = -40°C to +85°C, M = -55°C to +125°C
† Prices provided are for design guidance and are FOB USA. International prices will differ due to local duties, taxes, and exchange rates.
†† Future product - contact factory for pricing and availability.

POWER MANAGEMENT

MULTI-FUNCTION SUPPLIES

5 OR 6 CELL PORTABLES

★ **MAX714**
(2 at +5V, -26V LCD, µP super.)

★ **MAX715**
(3 at +5V, -26V LCD, -5V, +12V, µP super.)

★ **MAX716**
(4 at +5V, -26V LCD, -5V, +12V, µP super.)

LOW-SIDE MOSFET DRIVERS

★ **MAX626**
(4Ω, dual inverting)

★ **MAX627**
(4Ω, dual noninverting)

★ **MAX628**
(4Ω, dual mixed

★ **MAX4426**
(4Ω, dual inverting)

★ **MAX4427**
(4Ω, dual noninverting)

★ **MAX4428**
(4Ω, dual mixed)

★ **TSC426**
(10Ω, dual inverting)

★ **TSC427**
(10Ω, dual noninverting)

★ **TSC428**
(10Ω, dual mixed)

★ **ICL7667**
(8Ω, dual inverting)

HIGH-SIDE MOSFET DRIVERS

★ **MAX620** (quad)

★ **MAX621**
(quad, internal caps)

★ **MAX625**
(quad, built-in MOSFETs, internal caps)

OFFLINE AC-DC CONVERTERS

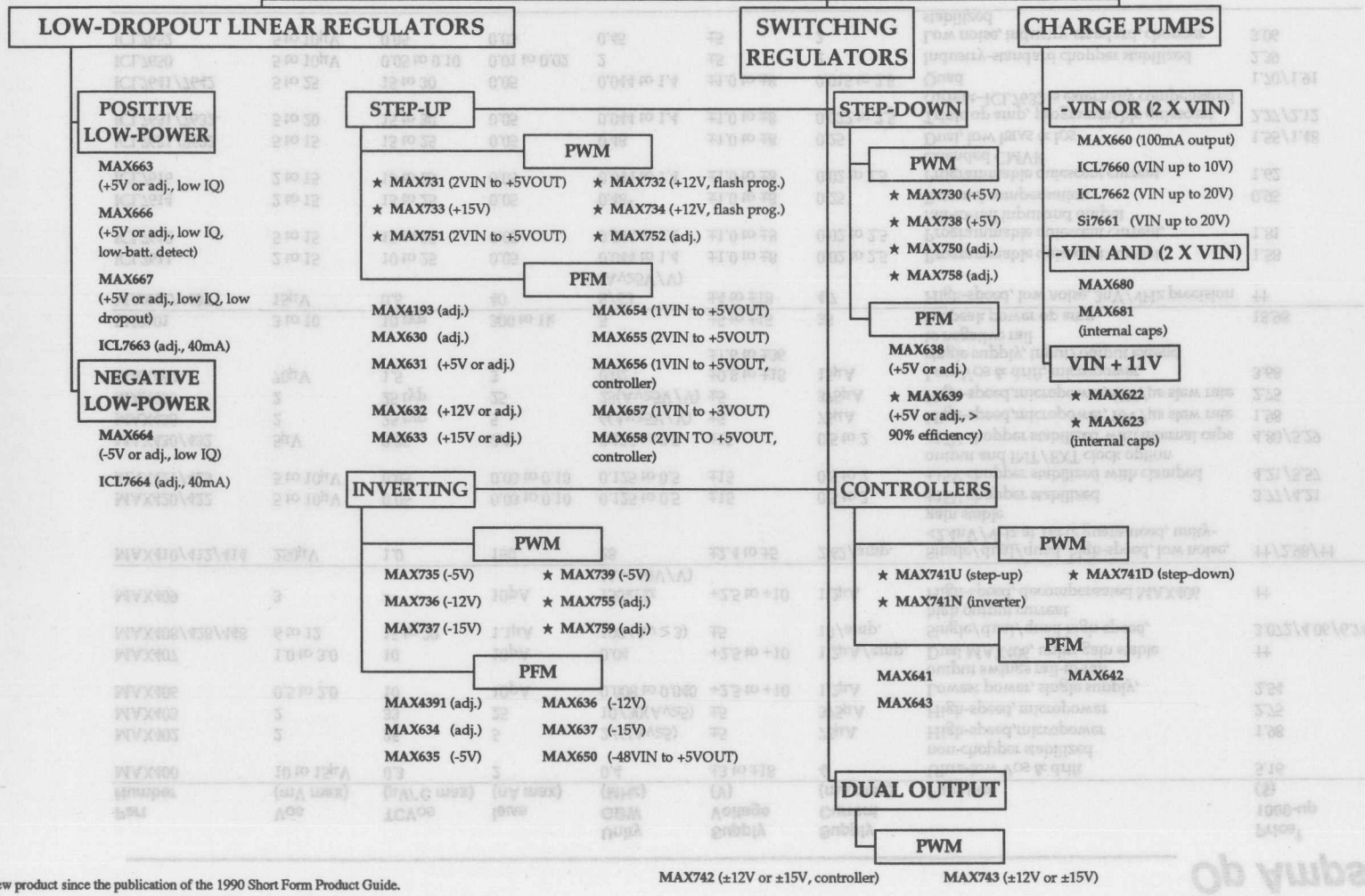
MAX610
(120V/240V line to 6V to 9V)

MAX611
(120V/240V line to 1.3V to 9V)

MAX612
(120V/240V line to 1.3V to 9V)

★ New product since the publication of the 1990 Short Form Product Guide.

DC-DC CONVERTERS



★ New product since the publication of the 1990 Short Form Product Guide.

Part Number	V_{OS} (mV max)	TCV_{OS} (µV/°C max)	I_{BIAS} (nA max)	Unity GBW (MHz)	Supply Voltage (V)	Supply Current (mA max)	Features	Price† 1000-up ($)
MAX400	10 to 15µV	0.3	2	0.4	±3 to ±18	4	Ultra-low V_{OS} & drift non-chopper stabilized	5.16
MAX402	2	25	5	2/6(A_V≥5)	±5	75µA	High-speed,micropower	1.98
MAX403	2	33	25	10/30(A_V≥5)	±5	375µA	High-speed, micropower	2.75
MAX406	0.5 to 2.0	10	10pA	0.008 to 0.040	+2.5 to +10	1.2µA	Lowest power, single supply, output swings rail-to-rail	2.54
MAX407	1.0 to 3.0	10	10pA	0.04	+2.5 to +10	1.2µA/amp.	Dual MAX406, unity-gain stable	††
MAX408/428/448	6 to 12	15 to 20	1.1µA	100 (A_V ≥ 3)	±5	10/amp.	Single/dual/quad high-speed, high output current	3.072/4.06/6.74
MAX409	3	-	10pA	150kHz (A_V≥10V/V)	+2.5 to +10	1.2µA	High-speed, decompensated MAX406	††
MAX410/412/414	250µV	1.0	150	28	±2.4 to ±5	2.62/amp.	Single/dual/quad, high-speed, low noise, <2.4nV/√Hz at 1kHz guaranteed, unity-gain stable	††/2.98/††
MAX420/422	5 to 10µV	0.05	0.03 to 0.10	0.125 to 0.5	±15	0.5 to 2	±15V chopper stabilized	3.77/4.21
MAX421/423	5 to 10µV	0.05	0.03 to 0.10	0.125 to 0.5	±15	0.5 to 2	±15V chopper stabilized with clamped output and INT/EXT clock option	4.21/5.57
MAX430/432	5µV	0.05	0.1	0.125 to 0.5	±15	0.5 to 2	±15V chopper stabilized with internal caps	4.80/5.29
MAX438	2	25 typ	5	6(A_V≥5V/V)	±5	75µA	High-speed,micropower; 10V/µs slew rate	1.98
MAX439	2	25 typ	25	25(A_V≥5V/V)	±5	375µA	High-speed,micropower; 48V/µs slew rate	2.75
MAX480	70µV	1.5	3	0.02	±0.8 to ±18 ±1.6 to ±36	15µA	Low V_{OS} & drift, micropower, single supply, input/output extend to negative rail	3.68
LH0101	3 to 10	10 typ	300 to 1k	5	±5 to ±15	35	5A peak power op amp	18.98
MAX427/437	15µV	0.6	40	8/63 (A_V≥5V/V)	±4 to ±18	4.7	High-speed, low noise, 3nV/√Hz precision	††
ICL7611	2 to 15	10 to 25	0.05	0.044 to 1.4	±1.0 to ±8	0.02 to 2.5	Programmable quiescent current	1.58
ICL7612	5 to 15	15 to 25	0.05	0.044 to 1.4	±1.0 to ±8	0.02 to 2.5	Programmable quiescent current, rail-to-rail input and output	1.81
ICL7614	2 to 15	15 to 25	0.05	0.48*	±1.0 to ±8	0.25	External compensation	0.95
ICL7616	2 to 15	15 to 25	0.05	0.044 to 1.4	±1.0 to ±8	0.02 to 2.5	Programmable quiescent current, extended CMVR	1.62
ICL7621/7622	5 to 15	15 to 25	0.05	0.48	±1.0 to ±8	0.25	Dual, low I_{BIAS} & I_{OS}	1.55/1.48
ICL7631/7632	5 to 20	15 to 30	0.05	0.044 to 1.4	±1.0 to ±8	0.022 to 2.5	Triple op amp, programmable quiescent current–ICL7632 is externally compensated	2.27/2.12
ICL7641/7642	5 to 25	15 to 30	0.05	0.044 to 1.4	±1.0 to ±8	0.015 to 2.5	Quad	1.70/1.91
ICL7650	5 to 10µV	0.05 to 0.10	0.01 to 0.02	2	±5	2	Industry-standard chopper stabilized	2.39
ICL7652	5 to 10µV	0.05	0.03	0.45	±5	2	Low noise, industry-standard, chopper stabilized	3.06

* External 39pF compensation capacitor added.
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†† Future product – contact factory for pricing and availability.

Op Amps (contin

Part Number	V_{OS} (μV max)	TCV_{OS} (μV/°C max)	I_{BIAS} (nA max)	Unity GBW (MHz)	Supply Voltage (V)	Supply Current (mA max)	Features	Pr 10 ($)
LT1001	15 to 60	0.6 to 1	2 to 4	0.8	±3 to ±18	2	Industry-standard precision	1.7
LT1028	40 to 80	0.8 to 1	90 to 180	75 (Av > 2)	±4 to ±18	9.5 to 10.5	Lowest noise, high-speed	4.2
OP07	25 to 150	0.6 to 2.5	2 to 12	0.6	±3 to ±18	4	Industry-standard precision	1.5
OP27	25 to 100	0.6 to 1.8	40 to 80	8	±3 to ±18	4.6 to 5.6	Industry-standard low noise	††
OP37	25 to 100	0.6 to 1.8	40 to 80	63 (Av ≥ 5)	±3 to ±18	4.6 to 5.6	Industry-standard low noise	††
OP90	150 to 450	2 to 5	15 to 25	0.020	±0.8 to ±18 ±1.6 to ±36	15 to 20μA	Industry-standard micropower	1.6
PGA100	1mV	6 typ	0.1 typ	5	æ15	27 (I_{cc})		56

Compar

Part Number	# Comps	Logic	Latched Outputs	Supply Current (mA max)	Tpd (ns typ)	Features	Pr 10 ($)
HIGH SPEED							
MAX900	4	TTL	Yes	15 (I_{cc})	8.0	Single +5V capability, low power, CMVR extends to neg. rail, separate analog & digital supplies, internal pull-up resistors	7.0
MAX901	4	TTL	No	15 (I_{cc})	8.0	MAX900 without output latch	5.9
MAX902	2	TTL	Yes	8 (I_{cc})	8.0	Dual MAX900	4.0
MAX903	1	TTL	Yes	4 (I_{cc})	8.0	Single MAX900	3.1
MAX905	1	ECL	Yes	24 (I_{ee})	1.8	Edge-triggered master/slave architecture eliminates oscillations and resolves 3mV input voltages	3.5
MAX906	2	ECL	Yes	48 (I_{ee})	1.8	Dual MAX905	5.2
MAX907	2	TTL	No	475μA/comp.	30	High speed, ultra low power, single +5V, 8-pin DIP/SO, 2mV hysteresis	††
MAX908	4	TTL	No	475μA/comp.	30	High speed, ultra low power, single +5V, 14-pin DIP/SO, 2mV hysteresis	††
MAX910	1	TTL	Yes	30 (I_{cc})	8.0	TTL-compatible, 8-bit digitally programmable input voltage threshold, on-board reference	5.2
MAX911	1	ECL	Yes	30 (I_{cc})	4.0	MAX910 with differential ECL outputs	5.2
MAX9685	1	ECL	Yes	32 (I_{ee})	1.3	Higher speed industry-standard	3.3
MAX9686	1	TTL	Yes	25 (I_{cc})	6.0	Higher speed industry-standard	2.3
MAX9687	2	ECL	Yes	68 (I_{ee})	1.4	Higher speed industry-standard	5.1
MAX9690	1	ECL	No	32 (I_{ee})	1.3	8-lead PDIP/SO	3.2
MAX9698	2	TTL	Yes	50 (I_{cc})	6.0	Higher speed industry-standard	3.9
SPECIAL							

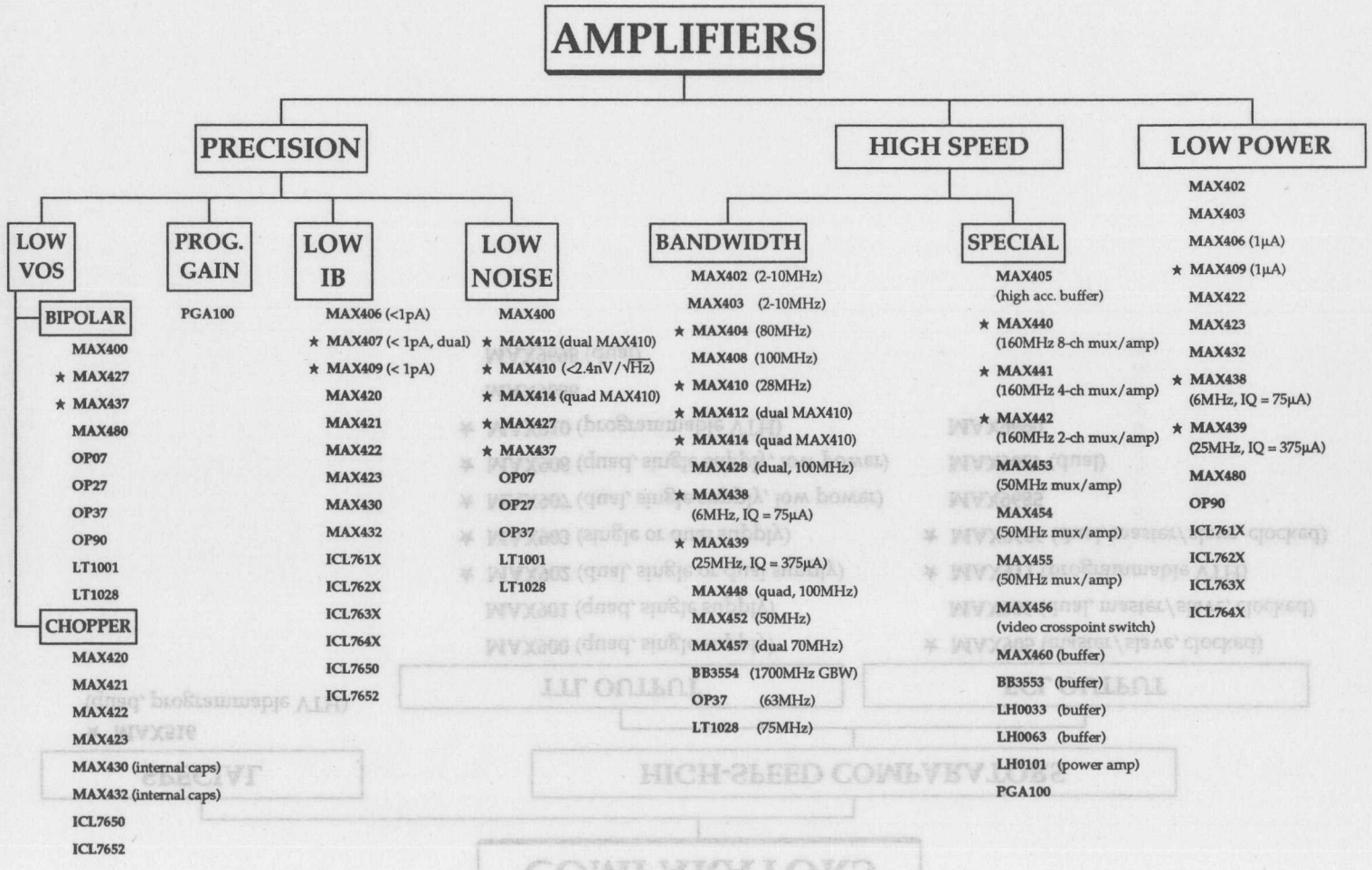
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Part Number	Unity GBW (MHz)	Slew Rate (V/µs)	V_{OS} (mV max)	Output Current (mA max)	Supply Voltage (V)	I_{BIAS} (nA max)	Features	Pr 10 ($)
VIDEO AMPLIFIERS								
MAX404	80 ($A_V \geq 2$)	500	8	50	±5	3µA	Broadcast-quality video op amp, 0.01°/0.05% diff phase/gain, symmetrical inputs, 70dB CMRR, 66dB A_{VOL}	2.6
MAX408/428/448	100($A_V \geq 3$)	90	6 to 12	50/amp.	±5	1.1µA	Single/dual/quad op amps, high output drive	3.0
MAX452	50	300	5	14	±5	10	Unity-gain stable, drives 75Ω coax cable	2.4
MAX457	70	300	5	15	±5	1	Dual, unity-gain stable, drives 75Ω coax cable	4.4
VIDEO BUFFERS								
MAX405	180	650	4	60	±5	2µA	Broadcast quality, 0.99V/V gain guaranteed over temp, 0.01°/0.03% diff phase/gain	4.2
MAX460	140	1500	5 to 10	100	±15	0.05 to 0.1	FET input, EL2005, LH0033 upgrade	19.
LH0033	100	1400 to 1500	5 to 20	100	±15	0.1 to 0.5	FET input, improved industry-standard	13.
LH0063/BB3553	300	2000	25 to 50	200	±15	0.2 to 0.5	FET input, industry-standard	23.
VIDEO MULTIPLEXER/AMPLIFIER								
MAX440	160 110($A_V \geq 2$)	370	10	24	±5	2µA	Video amp with 8-channel mux, 0.03°/0.04% diff phase/gain, 15ns switch time, high-Z output state	8.9
MAX441	160 110($A_V \geq 2$)	370	10	24	±5	2µA	Video amp with 4-channel mux, 0.03°/0.04% diff phase/gain, 15ns switch time	5.9
MAX442	160	370	5	24	±5	2µA	Video amp with 4-channel mux, 15ns switch time, 8-pin DIP/SO	4.4
MAX453	50	300	5	14	±5	10	Video amp with 2-channel video mux	3.9
MAX454	50	300	5	14	±5	10	Video amp with 4-channel video mux	5.2
MAX455	50	300	5	14	±5	10	Video amp with 8-channel video mux	8.7

Part Number	Unity GBW (MHz)	Slew Rate (V/µs)	V_{OS} (mV max)	OFF Isolation (dB at 5MHz)	Crosstalk (dB at 5MHz)	Features	Pr 10 ($)
VIDEO CROSSPOINT SWITCH							
MAX456	35	250	5	80	70	8x8 crosspoint switch array with 8 output buffers, three-state capability	19.

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AMPLIFIERS



★ New product since the publication of the 1990 Short Form Product Guide.

COMPARATORS

SPECIAL

★ **MAX516**
(quad, programmable VTH)

HIGH-SPEED COMPARATORS

TTL OUTPUT

MAX900 (quad, single supply)
MAX901 (quad, single supply)
★ **MAX902** (dual, single or dual supply)
★ **MAX903** (single or dual supply)
★ **MAX907** (dual, single supply, low power)
★ **MAX908** (quad, single supply, low power)
★ **MAX910** (programmable VTH)
MAX9686
MAX9698 (dual)

ECL OUTPUT

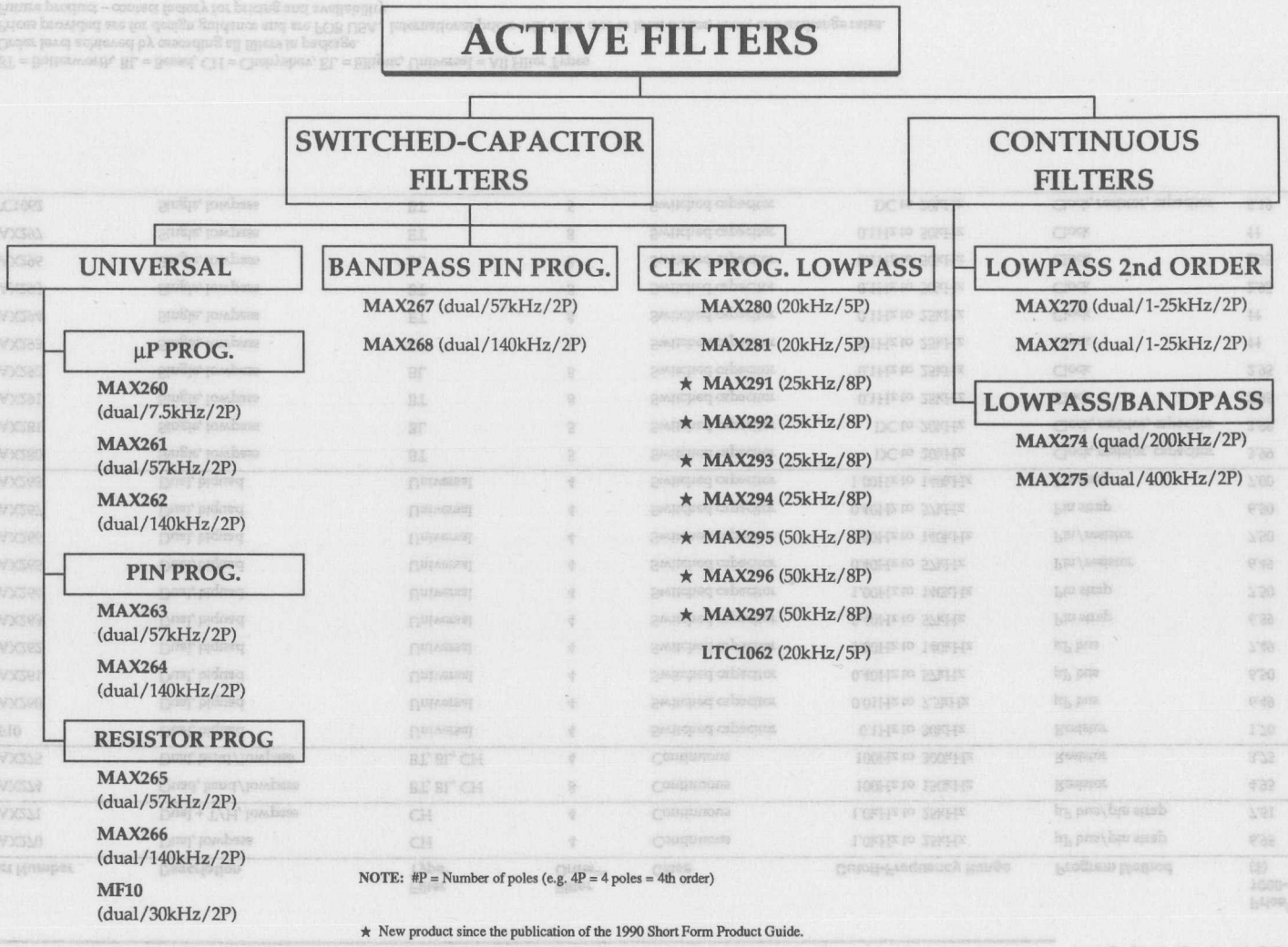
★ **MAX905** (master/slave, clocked)
MAX906 (dual, master/slave, clocked)
★ **MAX911** (programmable VTH)
★ **MAX9686** (dual, master/slave, clocked)
MAX9685
MAX9687 (dual)
MAX9690

★ New product since the publication of the 1990 Short Form Product Guide.

Part Number	Description	Filter Type*	Filter Order**	Class	Cutoff-Frequency Range	Program Method
MAX270	Dual, lowpass	CH	4	Continuous	1.0kHz to 25kHz	µP bus/pin strap
MAX271	Dual + T/H, lowpass	CH	4	Continuous	1.0kHz to 25kHz	µP bus/pin strap
MAX274	Quad, band/lowpass	BT, BL, CH	8	Continuous	100Hz to 150kHz	Resistor
MAX275	Dual, band/lowpass	BT, BL, CH	4	Continuous	100Hz to 300kHz	Resistor
MF10	Dual, biquad	Universal	4	Switched capacitor	0.1Hz to 30kHz	Resistor
MAX260	Dual, biquad	Universal	4	Switched capacitor	0.01Hz to 7.5kHz	µP bus
MAX261	Dual, biquad	Universal	4	Switched capacitor	0.40Hz to 57kHz	µP bus
MAX262	Dual, biquad	Universal	4	Switched capacitor	1.00Hz to 140kHz	µP bus
MAX263	Dual, biquad	Universal	4	Switched capacitor	0.40Hz to 57kHz	Pin strap
MAX264	Dual, biquad	Universal	4	Switched capacitor	1.00Hz to 140kHz	Pin strap
MAX265	Dual, biquad	Universal	4	Switched capacitor	0.40Hz to 57kHz	Pin/resistor
MAX266	Dual, biquad	Universal	4	Switched capacitor	1.00Hz to 140kHz	Pin/resistor
MAX267	Dual, biquad	Universal	4	Switched capacitor	0.40Hz to 57kHz	Pin strap
MAX268	Dual, biquad	Universal	4	Switched capacitor	1.00Hz to 140kHz	Pin strap
MAX280	Single, lowpass	BT	5	Switched capacitor	DC to 20kHz	Clock, resistor, capacito
MAX281	Single, lowpass	BL	5	Switched capacitor	DC to 20kHz	Clock, resistor, capacito
MAX291	Single, lowpass	BT	8	Switched capacitor	0.1Hz to 25kHz	Clock
MAX292	Single, lowpass	BL	8	Switched capacitor	0.1Hz to 25kHz	Clock
MAX293	Single, lowpass	ET	8	Switched capacitor	0.1Hz to 25kHz	Clock
MAX294	Single, lowpass	ET	8	Switched capacitor	0.1Hz to 25kHz	Clock
MAX295	Single, lowpass	BT	8	Switched capacitor	0.1Hz to 50kHz	Clock
MAX296	Single, lowpass	BL	8	Switched capacitor	0.1Hz to 50kHz	Clock
MAX297	Single, lowpass	ET	8	Switched capacitor	0.1Hz to 50kHz	Clock
LTC1062	Single, lowpass	BT	5	Switched capacitor	DC to 20kHz	Clock, resistor, capacito

* BT = Butterworth, BL = Bessel, CH = Chebyshev, EL = Elliptic, Universal = All Filter Types
** Order level achieved by cascading all filters in package.
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†† Future product – contact factory for pricing and availability.

ACTIVE FILTERS



NOTE: #P = Number of poles (e.g. 4P = 4 poles = 4th order)

★ New product since the publication of the 1990 Short Form Product Guide.

Voltage References

Part Number	Voltage	Temp. Drift (ppm/°C max)	Initial Accuracy T_A = +25°C (%F.S. max)	Quiescent Current (mA max)	Noise 0.1Hz-10Hz (μVp-p) max (typ)	Package Options[1]	Temp. Range[2]	Features	Price† 1000-up ($)
ICL8069	1.2	10 to 100	2	0.05	5 (10Hz - 10kHz)	TO-52, TO-92, SO*	C, M, E	Micropower two-terminal reference	0.98
MAX872	2.5	40	0.2	0.010	(60)	DIP, SO	C, E	$V_{CC} = V_{OUT}$ +,2V	2.14
MX580	2.5	10 to 85	0.4 to 3	1.5	(60)	TO-52, SO**	C, M	Low-drift bandgap reference	2.71
MX584	2.5	5 to 30	0.05 to 0.3	1	(50)	TO-99, DIP, SO, CERDIP	C, M	Low-drift, programmable reference	3.09
MAX874	4.096	40	0.2	0.010	(60)	DIP, SO	C, E	$V_{CC} = V_{OUT}$ +,2V	2.14
MAX675	5.0	12 to 20	0.15	1.4	15	DIP, SO, TO-99, CERDIP	C, E, M	Low-drift, low-noise bandgap reference	3.40
MX584	5.0	5 to 30	0.05 to 0.3	1	(50)	TO-99, DIP, SO, CERDIP	C, M	Low-drift, programmable reference	3.09
REF02	5.0	8.5 to 250	0.3 to 2	1.4	15	DIP, SO, TO-99, CERDIP	C, M	Low-drift bandgap reference	2.09
MX584	7.5	5 to 30	0.05 to 0.3	1	(50)	TO-99, DIP, SO, CERDIP	C, M	Low-drift, programmable reference	3.09
MAX670	10.0	3 to 10	0.025	14	50	SB Ceramic	E, M	Kelvin connected, ultra-low drift reference	32.78
MAX671	10.0	1 to 10	0.01	14	50	SB Ceramic	C, E, M	Kelvin connected, ultra-low drift reference	31.84
MAX674	10.0	12 to 20	0.15	1.4	30	DIP, SO, TO-99, CERDIP	C, E, M	Low-drift, low-noise bandgap reference	3.40
MX581	10.0	5 to 30	0.05 to 0.3	1	(50)	TO-39, SO***	C, M	Low-drift bandgap reference	3.07
MX584	10.0	5 to 30	0.05 to 0.3	1	(50)	TO-99, DIP, SO, CERDIP	C, M	Low-drift, programmable reference	3.09
MX2700	10.0	3 to 10	0.025 to 0.05	14	(50)	SB Ceramic	I, M	Ultra-low drift voltage reference	17.60
MX2710	10.0	1 to 5	0.01	14	(30)	SB Seramic	C	Ultra-low drift voltage reference	22.20
REF01	10.0	8.5 to 65	0.3 to 1	1.4	30	DIP, SO, TO-99, CERDIP	C, M	Low-drift bandgap reference	2.21
MX2701	-10.0	3 to 10	0.025 to 0.05	14	(50)	SB Ceramic	I, M	Ultra-low drift voltage reference	21.56

* The ICL8069 is available in a 2-pin TO-52 and TO-92 package, or an 8-pin SO package.
** The MX580 is avilable in a 3-pin TO-52 and 8-pin SO package.
*** The MX581 is available in a 3-pin TO-39 and 8-pin SO package.
[1] Package Options: DIP = Dual-In-Line Package, PLCC = Plastic Leaded Chip Carrier (quad pack), FP = Flat Pack
[2] Temp Ranges: C = 0°C to +70°C, I = -25°C to +85°C, E = -40°C to +85°C, M = -55°C to +125°C
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REFERENCES

VOLTAGE OUT

1.2 VOLTS

ICL8069
(10-100ppm/°C)

2.5 VOLTS

★ **MAX872**
(IQ = 10µA, 40ppm/°C)

MX580
(10-85ppm/°C)

MX584
(5-30ppm/°C)

4.0 VOLTS

★ **MAX874**
(IQ = 10µA, 40ppm/°C)

5.0 VOLTS

MAX675
(12-20ppm/°C)

MX584
(5-30ppm/°C)

REF02
(8.5-250ppm/°C)

7.5 VOLTS

MX584
(5-30ppm/°C)

10.0 VOLTS

MAX670
(3-10ppm/°C)

MAX671
(1-10ppm/°C)

MAX674
(12-20ppm/°C)

MX2700
(3-10ppm/°C)

MX2710
(1-5ppm/°C)

MX581
(5-30ppm/°C)

MX584
(5-30ppm/°C)

REF01
(8.5-65ppm/°C)

-10.0 VOLTS

MX2701
(3-10ppm/°C)

★ New product since the publication of the 1990 Short Form Product Guide.

General-Purpose A/D Conver

Part Number	Resolution (Bits)	Conversion Time (µs max)	Input Channels	Sample Rate (kHz max)	Reference Voltage* (V)	Data-Bus Interface (Bits)	Supply Voltage (V)	Input Ranges (V)	Features	Price 1000- ($)
MAX153	8	0.660	1	1000	E	µP/8	+5 & ±5	+5, ±2.5	High-speed A/D with powerdown	††
MX7821	8	0.660	1	1000	E	µP/8	+5 & ±5	+5, ±2.5	Complete A/D with T/H	7.54
MAX150	8	1.34	1	500	E/I/+2.5	µP/8	+5	+5	Complete A/D with T/H and ref	7.96
MX7820	8	1.34	1	500	E	µP/8	+5	+5	Plug-in replacement for AD7820	7.93
ADC0820	8	1.38	1	400	E	µP/8	+5	+5	Complete A/D with T/H	7.16
MAX154	8	2	4	300	E/I/+2.5	µP/8	+5	+5	4-Ch A/D with T/H and ref	8.36
MAX158	8	2	8	300	E/I/+2.5	µP/8	+5	+5	8-Ch A/D with T/H and ref	8.76
MX7824	8	2	4	300	E	µP/8	+5	+5	Plug-in replacement for AD7824	8.33
MX7828	8	2	8	300	E	µP/8	+5	+5	Plug-in replacement for AD7828	8.73
MAX155	8	3.8	8	250	E/I/+2.5	µP/8	+5	+2.5, ±2.5	8-Ch simultaneous T/H and ref	10.00
MAX156	8	3.8	4	250	E/I/+2.5	µP/8	+5	+2.5, ±2.5	4-Ch simultaneous T/H and ref	8.85
MAX160	8	4	1	-	E	µP/8	+5	+10, ±5	Ratiometric, single-supply A/D	7.20
MAX165	8	5	1	200	E/I/+1.23	µP/8	+5	+5	Complete sampling A/D with ref	4.99
MAX166	8	5	1	200	E/I/+1.23	µP/8	+5	+5	Differential input complete A/D	4.99
MX7575	8	5	1	200	E	µP/8	+5	+5	Plug-in replacement for AD7575	3.74
MX7576	8	10	1	-	E	µP/8	+5	+5	Plug-in replacement for AD7576	3.52
MX7574	8	15	1	-	E	µP/8	+5	+10, ±5	Plug-in replacement for AD7574	4.80
MAX161	8	20	8	-	E	µP/8	+5	+10	8-Ch A/D with RAM buffer	11.12
MX7581	8	66.6	8	-	E	µP/8	+5	+10	Plug-in replacement for AD7581	11.08
MAX151	10	2.5	1	300	E/I/+4.0	µP/10	±5	+5	Sampling A/D with ref	12.67
MAX173	10	5	1	-	I/-5.25	µP/8/12	+5 & -12/-15	+5	Complete with ref	7.01
MAX177	10	8.33	1	100	I/-5.25	µP/8/12	+5 & -12/-15	±2.5	Sampling A/D with ref	7.96
MAX120	12	1.6	1	500	I/-5.0	µP/12	+5 & -12/-15	±5	High-speed complete sampling A/D	††
MAX122	12	2.6	1	333	I/-5.0	µP/12	+5 & -12/-15	±5	High-speed complete sampling A/D	††
MX578	12	3	1	-	E/I/+10.0	Logic	+5 & ±15	±10	With parallel/serial outputs	88.7
MAX162	12	3.25	1	-	I/-5.25	µP/8/12	+5 & -12/-15	+5	High-speed A/D with internal ref	19.2
MAX183	12	3.25	1	-	E	µP/8/12	+5 & -12/-15	+5, ±5, +10	High-speed A/D with external ref	15.0
MX7672-03	12	3.25	1	-	E	µP/8/12	+5 &-12	+5, ±5, +10	Plug-in replacement for AD7672-03	57.3
MAX176	12	3.5	1	250	I/-5.0	Serial	+5 & -12/-15	±5	8-pin miniDIP	††
MAX170	12	5	1	-	I/-5.25	Serial/12	+5 & -12/-15	+5	8-pin miniDIP	11.9
MAX171	12	5	1	-	I/-5.25	Serial/12	+5 & -12/-15	+5	Opto-isolated	20.2
MAX184	12	5	1	-	E	µP/8/12	+5 & -12/-16	+5/±5/+10	High-speed A/D with external ref	13.7

* E = external reference, I = internal reference

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†† Future product- contact factory for pricing and availability.

General-Purpose A/D Converters (contin

Part Number	Resolution (Bits)	Conversion Time (µs max)	Input Channels	Sample Rate (kHz max)	Reference Voltage* (V)	Data-Bus Interface (Bits)	Supply Voltage (V)	Input Ranges (V)	Features	Pric 100 ($)
MX7572-05	12	5	1	-	I/-5.25	µP/8/12	+5 & -15	+5	Plug-in replacement for AD7572-05	20.0
MX7672-05	12	5	1	-	E	µP/8/12	+5 & -12	+5, ±5, +10	Plug-in replacement for AD7672-05	33.6
MAX186	12	7.5	8	133	E/I/+4.096	Serial	+5/±5	+5, ±2.5	7mW, 10µA powerdown	††
MAX187	12	7.5	1	133	E/I/+4.096	Serial	+5/±5	+5, ±2.5	7mW, 8-pin package	††
MAX188	12	7.5	8	133	E	Serial	+5/±5	+5, ±2.5	MAX186 without reference	††
MAX189	12	7.5	1	133	E	Serial	+5/±5	+5, ±2.5	MAX187 without reference	††
MAX191	12	7.5	1	100	E/I/+4.096	µP/12/serial	+5/±5	+5, ±2.5	15mW, 100µW powerdown	††
MAX190	12	7.8	1	100	E/I/+4.096	µP/12/serial	+5 & ±5	+5	Low-power sampling A/D with ref	10.0
MAX174	12	8	1	-	E/I/+10.0	µP/8/12	+5 & ±12/±15	±5, ±10, +10, +20	Upgrades for AD574A/AD674A	28.1
MAX163	12	8.33	1	100	I/-5.0	µP/8/12	+5 & -12/-15	+5	Complete sampling A/D with ref	14.4
MAX164	12	8.33	1	100	I/-5.0	µP/8/12	+5 & -12/-15	±5	Complete sampling A/D with ref	14.4
MAX167	12	8.33	1	100	I/-5.0	µP/8/12	+5 & -12/-15	±2.5	Complete sampling A/D with ref	14.4
MAX180	12	8.33	8	100	E/I/-5.0	µP/8/16	+5 & -12/-15	+5, ±2.5	Data-acquisition system	17.0
MAX181	12	8.33	6	100	E/I/-5.0	µP/8/16	+5 & -12/-15	+5, ±2.5	Data-acquisition system	17.0
MAX172	12	10	1	-	I/-5.25	µP/8/12	+5 & -12/-15	+5	First lowest-cost complete A/D	9.60
MAX185	12	10.4	1	-	E	µP/8/12	+5 & -12/-15	+5, ±5, +10	High-speed A/D with external ref	12.0
MX7672-10	12	10.4	1	-	E	µP/8/12	+5 & -12	+5, ±5, +10	Plug-in replacement for AD7672-05	25.2
MX7572-12	12	12	1	-	I/-5.25	µP/8/12	+5 & -15	+5	Plug-in replacement for AD7572-12	14.0
MX674A	12	15	1	-	E/I/+10.0	µP/8/12	+5 & ±12/±15	±5, ±10, +10, +20	Plug-in replacement for AD574A	23.44
MX574A	12	25	1	-	E/I/+10.0	µP/8/12	+5 & ±12/±15	±5, ±10, +10, +20	Plug-in replacement for AD674A	11.97
MAX178	12	50	1	20	E/I/+5.0	µP/8/16	+5 & +15 & -5	+5	Calibrated to 1LSB, with T/H, ref	15.24
MAX182	12	50	4	20	E/I/+5.0	µP/8/16	+5 & +15 & -5	+5	Calibrated to 1LSB, with T/H, ref	17.55
MX7578	12	100	1	-	E	µP/8/16	+5 & +15 & -5	+5	Plug-in replacement for AD7578	16.96
MX7582	12	100	4	-	E	µP/8/16	+5 & +15 & -5	+5	Plug-in replacement for AD7582	19.50
MAX121	14	2.0	1	400	I/-5.0	Serial	+5 & -12/-15	±5	High-speed, complete sampling A/D with DSP interface	††
MAX168	14	3.5	1	250	E/I/+3.0	µP/8/16	+5 & -5	±3	Complete sampling A/D	††
MAX135	15 + sign	10ms	1	-	E	µP/8	±5	±0.5	High-resolution A/D, <1mW	8.00
MAX132	18 + sign	10ms	1	-	E	Serial	±5	±0.5	Serial high-resolution A/D, <1mW	8.00

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Sampling A/D Converters

Part Number	Resolution (Bits)	Conversion Time (µs max)	Input Channels	Sample Rate (kHz max)	Reference Voltage* (V)	Data-Bus Interface (Bits)	Supply Voltage (V)	Input Ranges (V)	Features	Price† 1000-up ($)
MAX153	8	0.660	1	1000	E	µP/8	+5 & ±5	+5, ±2.5	High-speed A/D with powerdown	††
MX7821	8	0.660	1	1000	E	µP/8	+5 & ±5	+5, ±2.5	Complete A/D with T/H	7.54
MAX150	8	1.34	1	500	E/I/+2.5	µP/8	+5	+5	Complete A/D with T/H and ref	7.96
MX7820	8	1.34	1	500	E	µP/8	+5	+5	Plug-in replacement for AD7820	7.93
ADC0820	8	1.38	1	400	E	µP/8	+5	+5	Complete A/D with T/H	7.16
MAX154	8	2	4	300	E/I/+2.5	µP/8	+5	+5	4-Ch A/D with T/H and ref	8.36
MAX158	8	2	8	300	E/I/+2.5	µP/8	+5	+5	8-Ch A/D with T/H and ref	8.76
MX7824	8	2	4	300	E	µP/8	+5	+5	Plug-in replacement for AD7824	8.33
MX7828	8	2	8	300	E	µP/8	+5	+5	Plug-in replacement for AD7828	8.73
MAX155	8	3.8	8	250	E/I/+2.5	µP/8	+5	+2.5, ±2.5	8-Ch simultaneous T/H and ref	10.00
MAX156	8	3.8	4	250	E/I/+2.5	µP/8	+5	+2.5, ±2.5	4-Ch simultaneous T/H and ref	8.85
MAX165	8	5	1	200	E/I/+1.23	µP/8	+5	+5	Complete sampling A/D with ref	4.99
MAX166	8	5	1	200	E/I/+1.23	µP/8	+5	+5	Differential input complete A/D	4.99
MX7575	8	5	1	200	E	µP/8	+5	+5	Plug-in replacement for AD7575	3.74
MAX151	10	2.5	1	300	E/I/+4.0	µP/10	±5	+5	Sampling A/D with ref	12.67
MAX177	10	8.33	1	100	I/-5.25	µP/8/12	+5 & -12/-15	±2.5	Sampling A/D with ref	7.96
MAX120	12	1.6	1	500	I/-5.0	µP/12	+5 & -12/-15	±5	High-speed complete sampling A/D	††
MAX122	12	2.6	1	333	I/-5.0	µP/12	+5 & -12/-15	±5	High-speed complete sampling A/D	††
MAX176	12	3.5	1	250	I/-5.0	Serial	+5 & -12/-15	±5	8-pin miniDIP	††
MAX186	12	7.5	8	133	E/I/+4.096	Serial	+5/±5	+5, ±2.5	7mW, 10µA powerdown	††
MAX187	12	7.5	1	133	E/I/+4.096	Serial	+5/±5	+5, ±2.5	7mW, 8-pin package	††
MAX188	12	7.5	8	133	E	Serial	+5/±5	+5, ±2.5	MAX186 without reference	††
MAX189	12	7.5	1	133	E	Serial	+5/±5	+5, ±2.5	MAX187 without reference	††
MAX191	12	7.5	1	100	E/I/+4.096	µP/12/serial	+5/±5	+5, ±2.5	15mW, 100µW powerdown	††
MAX190	12	7.8	1	100	E/I/+4.096	µP/12/serial	+5 & ±5	+5	Low-power sampling A/D with ref	10.00
MAX163	12	8.33	1	100	I/-5.0	µP/8/12	+5 & -12/-15	+5	Complete sampling A/D with ref	14.40
MAX164	12	8.33	1	100	I/-5.0	µP/8/12	+5 & -12/-15	±5	Complete sampling A/D with ref	14.40
MAX167	12	8.33	1	100	I/-5.0	µP/8/12	+5 & -12/-15	±2.5	Complete sampling A/D with ref	14.40
MAX180	12	8.33	8	100	E/I/-5.0	µP/8/16	+5 & -12/-15	+5, ±2.5	Data-acquisition system	17.00
MAX181	12	8.33	6	100	E/I/-5.0	µP/8/16	+5 & -12/-15	+5, ±2.5	Data-acquisition system	17.00
MAX178	12	50	1	20	E/I/+5.0	µP/8/16	+5 & +15 & -5	+5	Calibrated to 1LSB, with T/H, ref	15.24
MAX182	12	50	4	20	E/I/+5.0	µP/8/16	+5 & +15 & -5	+5	Calibrated to 1LSB, with T/H, ref	17.55
MAX121	14	2.0	1	400	I/-5.0	Serial	+5 & -12/-15	±5	High-speed, complete sampling A/D with DSP interface	††
MAX168	14	3.5	1	250	E/I/+3.0	µP/8/16	+5 & -5	±3	Complete sampling A/D	††

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Multi-Channel A/D Converters

Part Number	Resolution (Bits)	Conversion Time (µs max)	Input Channels	Sample Rate (kHz max)	Reference Voltage* (V)	Data-Bus Interface (Bits)	Supply Voltage (V)	Input Ranges (V)	Features	Price† 1000-up ($)
MAX154	8	2	4	300	E/I/+2.5	µP/8	+5	+5	4-Ch A/D with T/H and ref	8.36
MAX158	8	2	8	300	E/I/+2.5	µP/8	+5	+5	8-Ch A/D with T/H and ref	8.76
MX7824	8	2	4	300	E	µP/8	+5	+5	Plug-in replacement for AD7824	8.33
MX7828	8	2	8	300	E	µP/8	+5	+5	Plug-in replacement for AD7828	8.73
MAX155	8	3.8	8	250	E/I/+2.5	µP/8	+5	+2.5, ±2.5	8-Ch simultaneous T/H and ref	10.00
MAX156	8	3.8	4	250	E/I/+2.5	µP/8	+5	+2.5, ±2.5	4-Ch simultaneous T/H and ref	8.85
MAX161	8	20	8	-	E	µP/8	+5	+10	8-Ch A/D with RAM buffer	11.12
MX7581	8	66.6	8	-	E	µP/8	+5	+10	Plug-in replacement for AD7581	11.08
MAX186	12	7.5	8	133	E/I/+4.096	Serial	+5/±5	+5, ±2.5	7mW, 10µA powerdown	††
MAX188	12	7.5	8	133	E	Serial	+5/±5	+5, ±2.5	MAX186 without reference	††
MAX180	12	8.33	8	100	E/I/-5.0	µP/8/16	+5 & -12/-15	+5, ±2.5	Data-acquisition system	17.00
MAX181	12	8.33	6	100	E/I/-5.0	µP/8/16	+5 & -12/-15	+5, ±2.5	Data-acquisition system	17.00
MAX182	12	50	4	20	E/I/+5.0	µP/8/16	+5 & +15 & -5	+5	Calibrated to 1LSB, with T/H, ref	17.55
MX7582	12	100	4	-	E	µP/8/16	+5 & +15 & -5	+5	Plug-in replacement for AD7582	19.50

Serial A/D Converters

Part Number	Resolution (Bits)	Conversion Time (µs max)	Input Channels	Sample Rate (kHz max)	Reference Voltage* (V)	Data-Bus Interface (Bits)	Supply Voltage (V)	Input Ranges (V)	Features	Price† 1000-up ($)
MAX176	12	3.5	1	250	I/-5.0	Serial	+5 & -12/-15	±5	8-pin miniDIP	††
MAX186	12	7.5	8	133	E/I/+4.096	Serial	+5/±5	+5, ±2.5	7mW, 10µA powerdown	††
MAX187	12	7.5	1	133	E/I/+4.096	Serial	+5/±5	+5, ±2.5	7mW, 8-pin package	††
MAX188	12	7.5	8	133	E	Serial	+5/±5	+5, ±2.5	MAX186 without reference	††
MAX189	12	7.5	1	133	E	Serial	+5/±5	+5, ±2.5	MAX187 without reference	††
MAX191	12	7.5	1	100	E/I/+4.096	µP/12/serial	+5/±5	+5, ±2.5	15mW, 100µW powerdown	††
MAX190	12	7.8	1	100	E/I/+4.096	µP/12/serial	+5 & ±5	+5	Low-power sampling A/D with ref	10.00
MAX121	14	2.0	1	400	I/-5.0	Serial	+5 & -12/-15	±5	High-speed, complete sampling A/D with DSP interface	††
MAX132	18 + sign	10ms	1	-	E	Serial	±5	±0.5	Serial high-resolution A/D, <1mW	8.00

* E = external reference, I = internal reference

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Part Number	Resolution (digits)	Resolution (counts)	Output Type	Supply Voltage (V)	Supply Current (mA) max (typ)	References	Features
MAX130	3 1/2	±2000	LCD	+4.5 to 14	.25 (0.1)	Bandgap	Replacement for ICL7106
MAX131	3 1/2	±2000	LCD	+4.5 to 14	.1 (0.06)	Bandgap	Replacement for ICL7136
MAX136	3 1/2	±2000	LCD	+9	.15 (0.06)	Bandgap	Hold function, low power
MAX138	3 1/2	±2000	LCD	+2.25 to 7	.8 (0.2)	Bandgap	± inputs with single supply
ICL7106	3 1/2	±2000	LCD	+9	.8 (0.6)	Zener	For digital multimeters
ICL7116	3 1/2	±2000	LCD	+9	.8 (0.8)	Zener	ICL7106 with display hold
ICL7126	3 1/2	±2000	LCD	+9	.1 (0.6)	Zener	Use ICL7136 for new designs
ICL7136	3 1/2	±2000	LCD	+9	.1 (0.06)	Zener	Low power/noise ICL7106
MAX139	3 1/2	±2000	LED	+5	.8 (0.2)	Bandgap	± inputs with single supply
MAX140	3 1/2	±2000	LED	+5	.8 (0.2)	Bandgap	Low segment current (2mA)
ICL7107	3 1/2	±2000	LED	+9	.8 (0.6)	Zener	For digital panel meters
ICL7117	3 1/2	±2000	LED	±5	.8 (0.8)	Zener	ICL7107 with display hold
ICL7137	3 1/2	±2000	LED	±5	.2 (0.06)	Zener	Low power when LEDs off
MAX133	3 3/4	±40,000	µP	+9	.2 (0.09)	External	20 conv/sec, ±10µV resolution
MAX134	3 3/4	±40,000	µP	±5	.2 (0.09)	External	20 conv/sec, ±10µV resolution
ICL7109	12 bits + sign	±4096	8-/16-bit µP/UART	±5	1.5 (0.7)	Zener	3-state binary outputs
ICL7129A	4 1/2	±20,000	Triplexed LCD	+9	1.4 (1.0)	External	Lowest noise ±3µV
ICL7135	4 1/2	±20,000	Multiplexed BCD	±5	2.0 (1.0)	External	For DMM, DPM, data loggers
MAX135	15 bits + sign	±20,000	µP/8	±5	0.125(0.06)	External	3-state twos-complement outputs
MAX132	18 bits + sign	±260,000	Serial µP	±5	0.125(0.06)	External	Serial low-power A/D

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A/D CONVERTERS

FAST CONVERSION (<100µs) (SEE SAR/FLASH A/Ds)

SLOW CONVERSION (>50ms) (INTEGRATING A/Ds)

LCD DISPLAY

MAX130 (3 1/2 D, B/G)
MAX131 (3 1/2 D, D/G, L)
MAX136 (3 1/2 D, Z, L)
MAX138 (3 1/2 D, B/G, S/S)
ICL7106 (3 1/2 D, Z)
ICL7116 (3 1/2 D, Z, HOLD)
ICL7126 (3 1/2 D, Z, L)
ICL7129A (4 1/2 D)
ICL7136 (3 1/2 D, Z, L)

LED DISPLAY

MAX139 (3 1/2 D, B/G, S/S)
MAX140 (3 1/2 D, B/G, S/S)
ICL7107 (3 1/2 D, Z)
ICL7117 (3 1/2 D, Z, HOLD)
ICL7137 (3 1/2 D, Z, L)

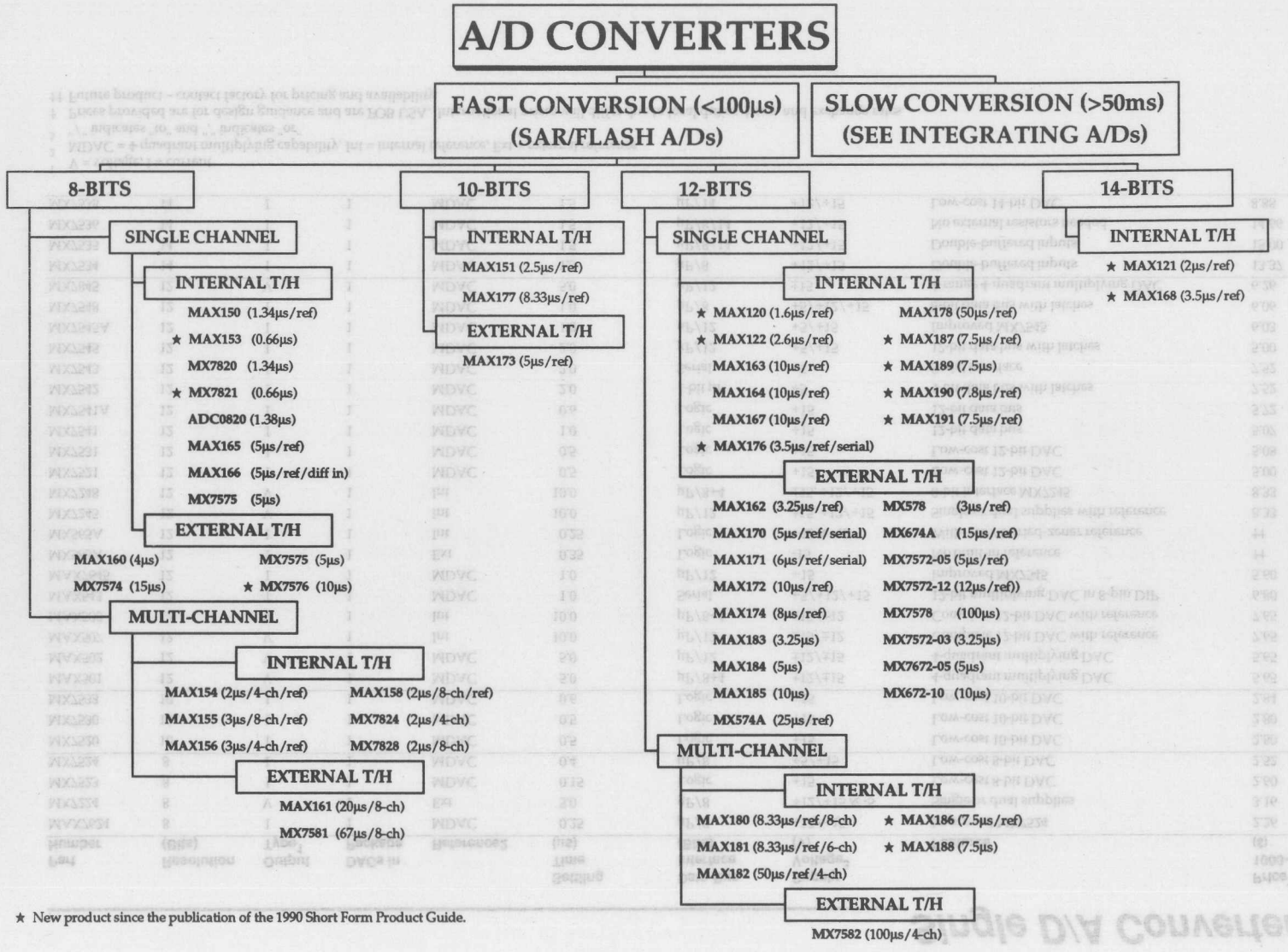
µP INTERFACE

★ **MAX132** (±18 bit, serial ou
MAX133 (±40,000 count, L)
MAX134 (±40,000 count, L)
★ **MAX135** (±15 bit)
ICL7109 (12 bit, Z)
ICL7135 (±20,000 count)

NOTES: HOLD - Has display-hold input
S/S - Has +5V single supply
B/G - Has bandgap reference
Z - Has zener reference
L - Low power

★ New product since the publication of the 1990 Short Form Product Guide.

A/D CONVERTERS



★ New product since the publication of the 1990 Short Form Product Guide.

Single D/A Converters

Part Number	Resolution (Bits)	Output Type[1]	DACs in Package	Reference2	Settling Time (µs)	Data-Bus Interface (Bits)	Supply Voltage[3] (V)	Features	Price† 1000-up ($)
MAX7624	8	I	1	MDAC	0.25	µP/8	+12/+15	Improved MX7524	2.26
MX7224	8	V	1	Ext	5.0	µP/8	+12/+15 & -5	Single or dual supplies	3.16
MX7523	8	I	1	MDAC	0.15	Logic	+15	Low-cost 8-bit DAC	2.60
MX7524	8	I	1	MDAC	0.4	µP/8	+5/+15	Low-cost 8-bit DAC	2.52
MX7520	10	I	1	MDAC	0.5	Logic	+15	Low-cost 10-bit DAC	2.80
MX7530	10	I	1	MDAC	0.5	Logic	+15	Low-cost 10-bit DAC	2.80
MX7533	10	I	1	MDAC	0.6	Logic	+15	Low-cost 10-bit DAC	2.84
MAX501	12	V	1	MDAC	5.0	µP/8+4	±12/±15	4-quadrant multiplying DAC	5.65
MAX502	12	V	1	MDAC	5.0	µP/12	±12/±15	4-quadrant multiplying DAC	5.65
MAX507	12	V	1	Int	10.0	µP/12	±15/±12	Complete 12-bit DAC with reference	7.65
MAX508	12	V	1	Int	10.0	µP/8+4	±15/±12	Complete 12-bit DAC with reference	7.65
MAX543	12	I	1	MDAC	1.0	Serial	+5/+12/+15	12-bit multiplying DAC in 8-pin DIP	6.80
MAX7645	12	I	1	MDAC	1.0	µP/12	+15	Improved MX7545	5.60
MX566A	12	I	1	Ext	0.35	Logic	-15	No built-in reference	††
MX565A	12	I	1	Int	0.25	Logic	+15 & -15	With +10V buried-zener reference	††
MX7245	12	V	1	Int	10.0	µP/12	±15, +12/+15	Single or dual supplies with reference	8.33
MX7248	12	V	1	Int	10.0	µP/8+4	±15, +12/+15	8-bit interface MX7245	8.33
MX7521	12	I	1	MDAC	0.5	Logic	+15	Low-cost 12-bit DAC	5.00
MX7531	12	I	1	MDAC	0.5	Logic	+15	Low-cost 12-bit DAC	5.08
MX7541	12	I	1	MDAC	1.0	Logic	+15	12-bit data bus	5.07
MX7541A	12	I	1	MDAC	0.6	Logic	+15	12-bit data bus	5.72
MX7542	12	I	1	MDAC	2.0	4-bit µP	+5	4-bit data bus with latches	7.52
MX7543	12	I	1	MDAC	2.0	Serial	+5	Serial interface	7.52
MX7545	12	I	1	MDAC	2.0	µP/12	+5/+15	12-bit data bus with latches	5.00
MX7545A	12	I	1	MDAC	1.0	µP/12	+5/+15	Improved MX7545	6.03
MX7548	12	I	1	MDAC	1.0	µP/8	+5/+12/+15	8-bit data bus with latches	6.06
MX7845	12	V	1	MDAC	5.0	µP/12	±15	4-range 4-quadrant multiplying DAC	6.26
MX7534	14	I	1	MDAC	1.5	µP/8	+12/+15	Double-buffered inputs	13.37
MX7535	14	I	1	MDAC	1.5	µP/8/14	+12/+15	Double-buffered inputs	15.00
MX7536	14	I	1	MDAC	1.5	µP/8/14	+12/+15	No external resistors needed	14.66
MX7538	14	I	1	MDAC	1.5	µP/14	+12/+15	Low-cost 14-bit DAC	8.88

[1] V = voltage, I = current
[2] MDAC = 4-quadrant multiplying capability, Int = internal reference, Ext = external reference
[3] "/" indicates "to" and "," indicates "or"
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†† Future product – contact factory for pricing and availability.

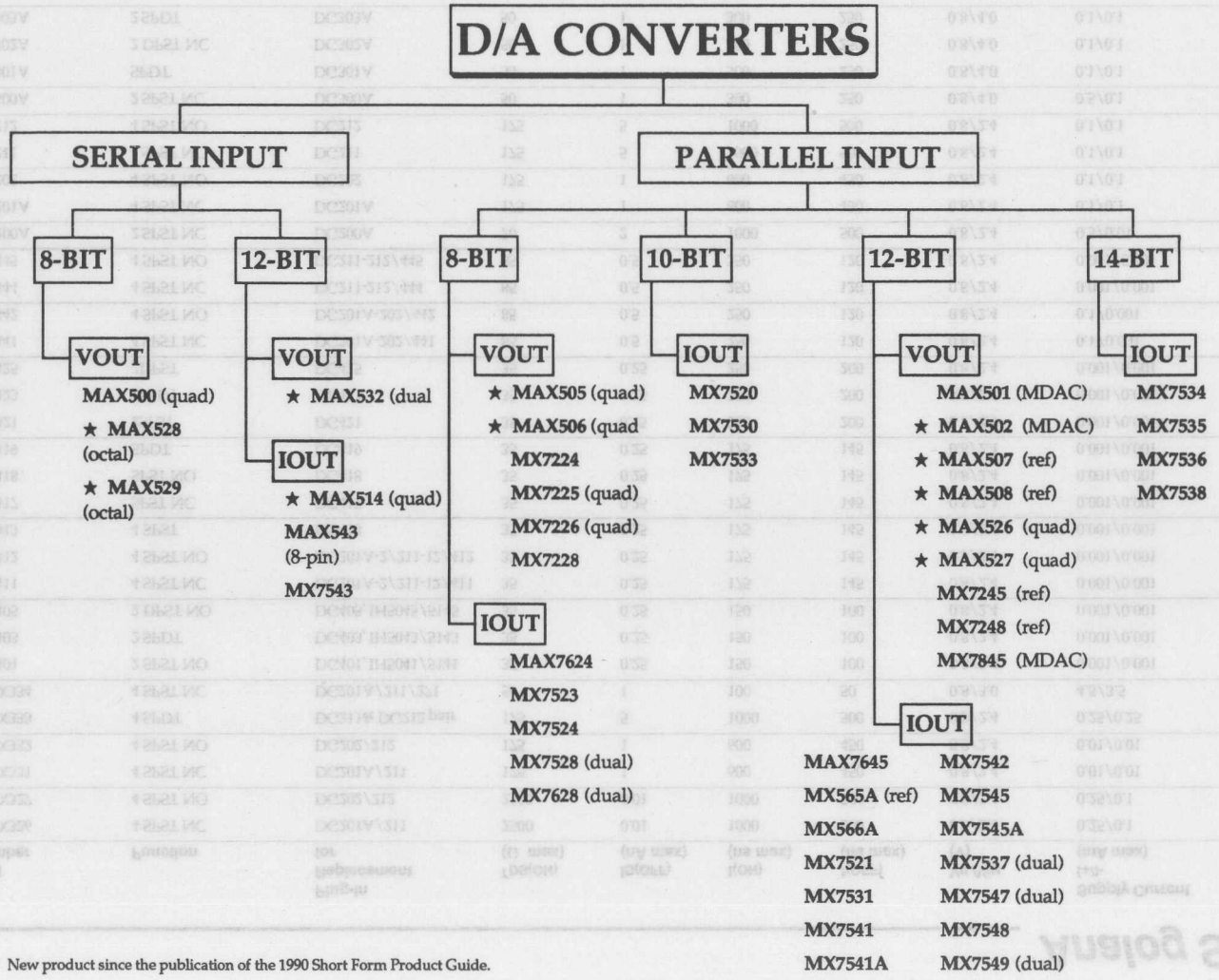
Part Number	Resolution (Bits)	Output Type[1]	DACs in Package	Reference[2]	Settling Time (µs)	Data-Bus Interface (Bits)	Supply Voltage[3] (V)	Features	Pri 10 ($)
DUAL									
MX7528	8	I	2	MDAC	0.18	µP/8	+5/+15	Data latches for both DACs	3.7
MX7628	8	I	2	MDAC	0.35	µP/8	+12/+15	Data latches for both DACs	3.8
MAX532	12	V	2	MDAC	4.0	Serial	±12/±15	16-pin DIP/SO	††
MX7537	12	I	2	MDAC	1.5	µP/8	+12/+15	Dual DAC with 8-bit data bus	11
MX7547	12	I	2	MDAC	1.5	µP/12	+12/+15	Dual DAC with 12-bit data bus	11
MX7549	12	I	2	MDAC	1.5	µP/4	+15	Dual DAC with 4-bit data bus	12
QUAD									
MAX500	8	V	4	Ext	4.0	Serial	+12/+15 & -5	Single or dual supplies	5.7
MAX505	8	V	4	MDAC	6.0	µP/8	+5/±5	Double-buffered logic, separate reference inputs	6.9
MAX506	8	V	4	MDAC	6.0	µP/8	+5/±5	Single-buffered logic, single reference input	6.1
MX7225	8	V	4	Ext	4.0	µP/8	+12/+15 & -5	Double buffered	14
MX7226	8	V	4	Ext	4.0	µP/8	+12/+15 & -5	Single buffered	11
MAX514	12	I	4	MDAC	1.0	Serial	+5/+15	Quad current-output DACs, available in DIP/SO	15
MAX526	12	V	4	Ext	3.0	µP/8+4	+12/+15 & -5	Quad voltage-output DACs, available in DIP/SO	21
MAX527	12	V	4	Ext	3.0	µP/8+4	±5	±5V version of MAX526	21
OCTAL									
MAX528	8	V	8	Ext	5.0	Serial	+5/+15, +15 & -5, +5 & -15	µP-selected buffered and unbuffered output	6.9
MAX529	8	V	8	Ext	5.0	Serial	+5	Single +5V supply MAX528	5.4
MX7228	8	V	8	Ext	5.0	µP/8	+5/+15 & -5, +15	Single or dual supplies	24

[1] V = voltage, I = current
[2] MDAC = 4-quadrant multiplying capability, Int = internal reference, Ext = external reference
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†† Future product – contact factory for pricing and availability.

Part Number	Resolution (Bits)	Output Current Voltage[1]	DACs in Package	Reference[2]	Settling Time (µs)	Data-Bus Interface (Bits)	Supply Voltage[3] (V)	Features
MAX500	8	V	4	Ext	4.0	Serial	+12/+15 & -5	Single or dual supplies
MAX528	8	V	8	Ext	5.0	Serial	+5/+15, +15 & -5, +5 & -15	µP-selected buffered and unbuffered output
MAX529	8	V	8	Ext	5.0	Serial	+5	Single +5V supply MAX528
MAX514	12	I	4	MDAC	1.0	Serial	+5	Quad current-output DACs, available in DIP/SO
MAX532	12	V	2	MDAC	4.0	Serial	±12/±15	16-pin DIP/SO
MAX543	12	I	1	MDAC	1.0	Serial	+5/+12/+15	8-pin AD7543 replacement
MX7543	12	I	1	MDAC	2.0	Serial	+5	Serial interface

[1] V = voltage, I = current
[2] MDAC = 4-quadrant multiplying capability, Int = internal reference, Ext = external reference
[3] "/" indicates "to" and "," indicates "or"
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D/A CONVERTERS



★ New product since the publication of the 1990 Short Form Product Guide.

Part Number	Function	Plug-In Replacement for	$r_{DS(ON)}$ (Ω max)	$I_{D(OFF)}$ (nA max)	$t_{(ON)}$ (ns max)	$t_{(OFF)}$ (ns max)	V_{IL}/V_{IH} (V)	Supply Current I+/I- (mA max)	Price† 1000-up ($)
MAX326	4 SPST NC	DG201A/211	2500	0.01	1000	500	0.8/2.4	0.25/0.1	3.63
MAX327	4 SPST NO	DG202/212	2500	0.01	1000	500	0.8/2.4	0.25/0.1	3.63
MAX331	4 SPST NC	DG201A/211	175	1	600	450	0.8/2.4	0.01/0.01	6.73
MAX332	4 SPST NO	DG202/212	175	1	600	450	0.8/2.4	0.01/0.01	6.73
MAX333	4 SPDT	DG211& DG212 pair	175	5	1000	500	0.8/2.4	0.25/0.25	4.47
MAX334	4 SPST NC	DG201A/211/271	50	1	100	50	0.8/3.0	4.5/3.5	3.20
DG401	2 SPST NO	DG401, IH5041/5141	35	0.25	150	100	0.8/2.4	0.001/0.001	††
DG403	2 SPDT	DG403, IH5043/5143	35	0.25	150	100	0.8/2.4	0.001/0.001	††
DG405	2 DPST NO	DG405, IH5045/5145	35	0.25	150	100	0.8/2.4	0.001/0.001	††
DG411	4 SPST NC	DG201A-2/211-12/411	35	0.25	175	145	0.8/2.4	0.001/0.001	2.96
DG412	4 SPST NO	DG201A-2/211-12/412	35	0.25	175	145	0.8/2.4	0.001/0.001	2.96
DG413	4 SPST	DG413	35	0.25	175	145	0.8/2.4	0.001/0.001	2.96
DG417	SPST NC	DG417	35	0.25	175	145	0.8/2.4	0.001/0.001	††
DG418	SPST NO	DG418	35	0.25	175	145	0.8/2.4	0.001/0.001	††
DG419	SPDT	DG419	35	0.25	175	145	0.8/2.4	0.001/0.001	††
DG421	2SPST	DG421	35	0.25	250	200	0.8/2.4	0.001/0.001	††
DG423	2SPDT	DG423	35	0.25	250	200	0.8/2.4	0.001/0.001	††
DG425	2DPST	DG425	35	0.25	250	200	0.8/2.4	0.001/0.001	††
DG441	4 SPST NC	DG201A-202/441	85	0.5	250	120	0.8/2.4	0.1/0.001	2.48
DG442	4 SPST NO	DG201A-202/442	85	0.5	250	120	0.8/2.4	0.1/0.001	2.63
DG444	4 SPST NC	DG211-212/444	85	0.5	250	120	0.8/2.4	0.001/0.001	1.19
DG445	4 SPST NO	DG211-212/445	85	0.5	250	120	0.8/2.4	0.001/0.001	1.44
DG200A	2 SPST NC	DG200A	70	2	1000	500	0.8/2.4	0.3/0.01	1.78
DG201A	4 SPST NC	DG201A	175	1	600	450	0.8/2.4	0.1/0.1	1.97
DG202	4 SPST NO	DG202	175	1	600	450	0.8/2.4	0.1/0.1	2.21
DG211	4 SPST NC	DG211	175	5	1000	500	0.8/2.4	0.1/0.1	1.47
DG212	4 SPST NO	DG212	175	5	1000	500	0.8/2.4	0.1/0.1	1.47
DG300A	2 SPST NC	DG300A	50	1	300	250	0.8/4.0	0.5/0.1	2.15
DG301A	SPDT	DG301A	50	1	300	250	0.8/4.0	0.1/0.1	2.15
DG302A	2 DPST NC	DG302A	50	1	300	250	0.8/4.0	0.1/0.1	2.78
DG303A	2 SPDT	DG303A	50	1	300	250	0.8/4.0	0.1/0.1	2.78

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Analog Switches (continu

Part Number	Function	Plug-In Replacement for	$r_{DS(ON)}$ (Ω max)	$I_{D(OFF)}$ (nA max)	$t_{(ON)}$ (ns max)	$t_{(OFF)}$ (ns max)	V_{IL}/V_{IH} (V)	Supply Current I+/I- (mA max)	Price† 1000-u ($)
DG304A	2 SPST NC	DG304A	50	1	250	150	3.5/11.0	0.1/0.1	2.42
DG305A	SPDT	DG305A	50	1	250	150	3.5/11.0	0.1/0.1	2.55
DG306A	2 DPST NC	DG306A	50	1	250	150	3.5/11.0	0.1/0.1	4.06
DG307A	2 SPDT	DG307A	50	1	250	150	3.5/11.0	0.1/0.1	2.78
DG308A	SPST NO	DG308A	100	1	200	150	3.1/11.0	0.1/0.1	2.16
DG309	SPST NC	DG309	100	1	200	150	3.5/11.0	0.1/0.1	2.16
HI201	4 SPST NC	DG201A, HI201	70	5	400	300	0.8/2.4	0.3/0.1	2.00
DG381A	2 SPST NO	DG381A	50	1	300	250	0.8/4.0	0.1/0.1	3.24
DG384A	2 DPDT NC	DG384A	50	1	300	250	0.8/4.0	0.1/0.1	4.06
DG387A	SPDT	DG387A	50	1	300	250	0.8/4.0	0.1/0.1	3.24
DG390A	2 SPDT	DG390A	50	1	300	250	0.8/4.0	0.1/0.1	3.26
IH5041	2 SPST NC	IH5041	75	1	400	200	0.8/2.4	0.001/0.001	1.84
IH5043	2 SPDT	IH5043	75	1	400	200	0.8/2.4	0.001/0.001	2.36
IH5045	2 DPST NC	IH5045	75	1	400	200	0.8/2.4	0.001/0.001	2.44
IH5047	2 DPST NC	IH5045	75	1	400	200	0.8/2.4	0.001/0.001	2.44

Analog Multiplex

Part Number	Function	Plug-In Replacement for	$r_{DS(ON)}$ (Ω max)	$I_{D(OFF)}$ (nA max)	$t_{(ON)}/t_{(OFF)}$ (µs max)	Analog-Signal Voltage Range (V)	Features	I ((
MAX328	1-of-8	DG508	2500	0.02	1	±15	Ultra-low leakage	4
MAX329	2-of-8	DG509	2500	0.02	1	±15	Ultra-low leakage	4
MAX358	1-of-8	DG508, HI508A	1500	1.0	0.5	-12.5 to +13.5	Fault protected to ±35V	3
MAX359	2-of-8	DG509, HI509A	1500	1.0	0.5	-12.5 to +13.5	Fault protected to ±35V	3
MAX368	1-of-8	DG528	1500	2	1.5/1.0	-12.5 to +13.5	Fault protected with latches to ±35V	4
MAX369	2-of-8	DG529	1500	1.0	1.5/1.0	-12.5 to +13.5	Fault protected with latches to ±35V	4
MAX378	1-of-8	DG508, HI508A	3000	1.0	0.75/0.5	-12.5 to +13.5	Fault protected to ±75V	5
MAX379	2-of-8	DG509, HI509A	3000	1.0	0.75/0.5	-12.5 to +13.5	Fault protected to ±75V	5
MAX388	1-of-8	DG528, MAX368	3000	1.0	1	-12.5 to +13.5	Fault protected with latches to ±100V	(
MAX389	2-of-8	DG529, MAX369	3000	1.0	1	-12.5 to +13.5	Fault protected with latches to ±100V	(

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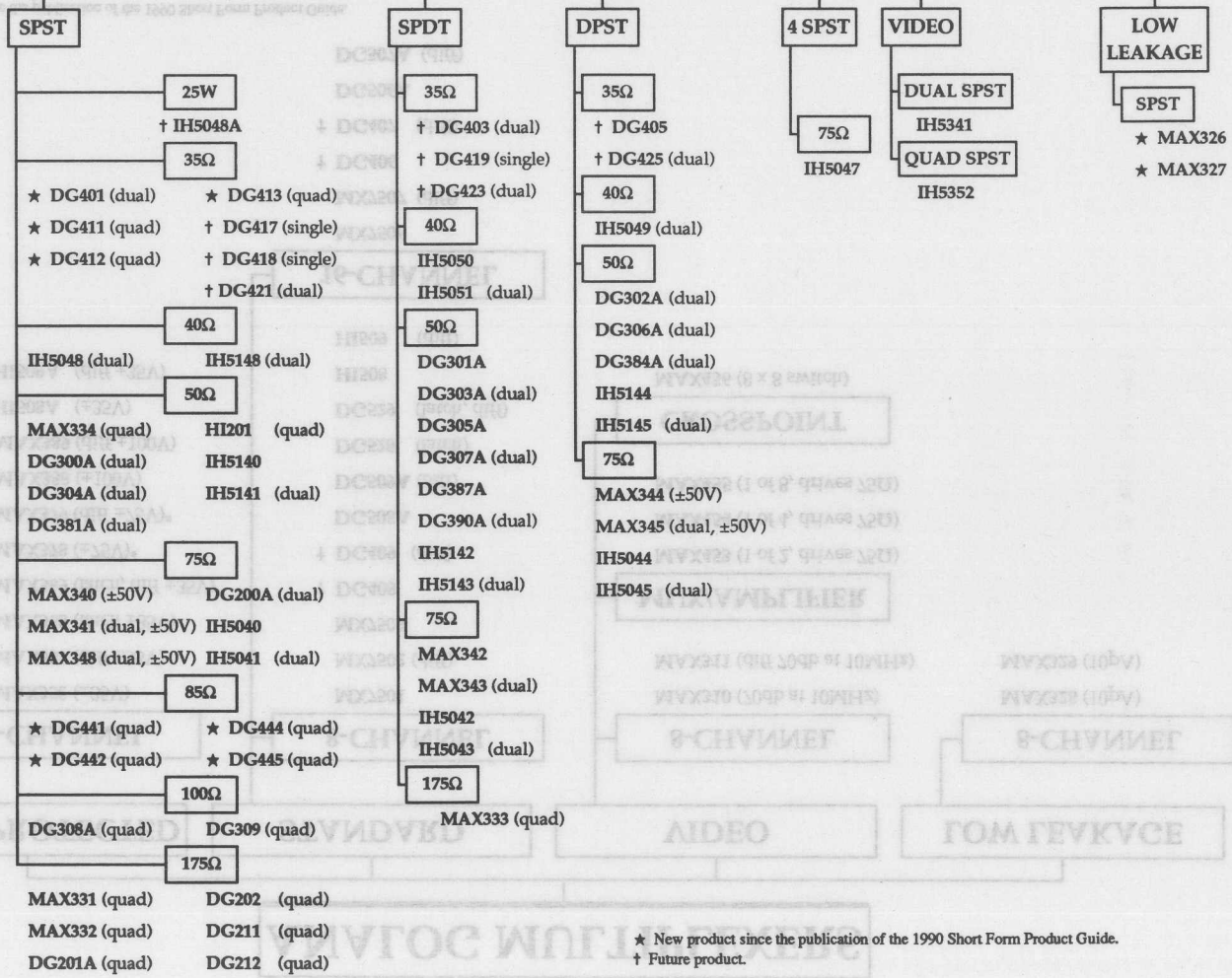
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†† Future product – contact factory for pricing and availability.

Analog Multiplexers (contin

Part Number	Function	Plug-In Replacement for	$r_{DS(ON)}$ (Ω max)	$I_{D(OFF)}$ (nA max)	$t_{(ON)}/t_{(OFF)}$ (μs max)	Analog-Signal Voltage Range (V)	Features	P 1 (
MX7501	1-of-8	AD7501	300	5	1.5/1.0	±15	Industry standard	5
MX7502	2-of-8	AD7502	300	3	1.5/1.0	±15	Industry standard	5
MX7503	1-of-8	AD7503	300	5	1.5/1.0	±15	Industry standard	5
MX7506	1-of-16	AD7506	400	5	1.5/1.0	±15	Industry standard	1
MX7507	2-of-16	AD7507	400	5	1.5/1.0	±15	Industry standard	1
DG406	1-of-16	DG406/506A	100	2	0.2/0.15	±15	Industry standard	†
DG407	2-of-16	DG407/507A	100	2	0.2/0.15	±15	Industry standard	†
DG408	1-of-8	DG408/508A	100	1	0.225/0.150	±15	Industry standard	†
DG409	2-of-8	DG409/509A	100	1	0.225/0.150	±15	Industry standard	†
DG506A	1-of-16	DG506A, HI506	400	5	1.0/0.4 (typ)	±15	Industry standard	4
DG507A	2-of-16	DG507A, HI507	400	5	1.0/0.4 (typ)	±15	Industry standard	4
DG508A	1-of-8	DG508A, HI508	300	2	1.0/1.7	±15	Industry standard	2
DG509A	2-of-8	DG509A, HI509	300	2	1.0/1.7	±15	Industry standard	2
DG528	1-of-8	DG528	400	10	1.5	±15	Industry standard	3
DG529	2-of-8	DG529	400	10	1.5	±15	Industry standard	3
HI508A	1-of-8	HI508A	1500	2	0.5	-12.5 to +13.5	Overvoltage	5
HI509A	2-of-8	HI509A	1500	2	0.5	-12.5 to +13.5	Overvoltage	5
IH5108	Use MAX358 (pin for pin compatible upgrade)							
IH5208	Use MAX359 (pin for pin compatible upgrade)							
IH6108	Use DG508A (pin for pin compatible upgrade)							
IH6208	Use DG509A (pin for pin compatible upgrade)							
IH6116	Use DG506A (pin for pin compatible upgrade)							
IH6216	Use DG507A (pin for pin compatible upgrade)							
HI506	Use DG506A (pin for pin compatible upgrade)							
HI507	Use DG507A (pin for pin compatible upgrade)							
HI508	Use DG508A (pin for pin compatible upgrade)							
HI509	Use DG509A (pin for pin compatible upgrade)							

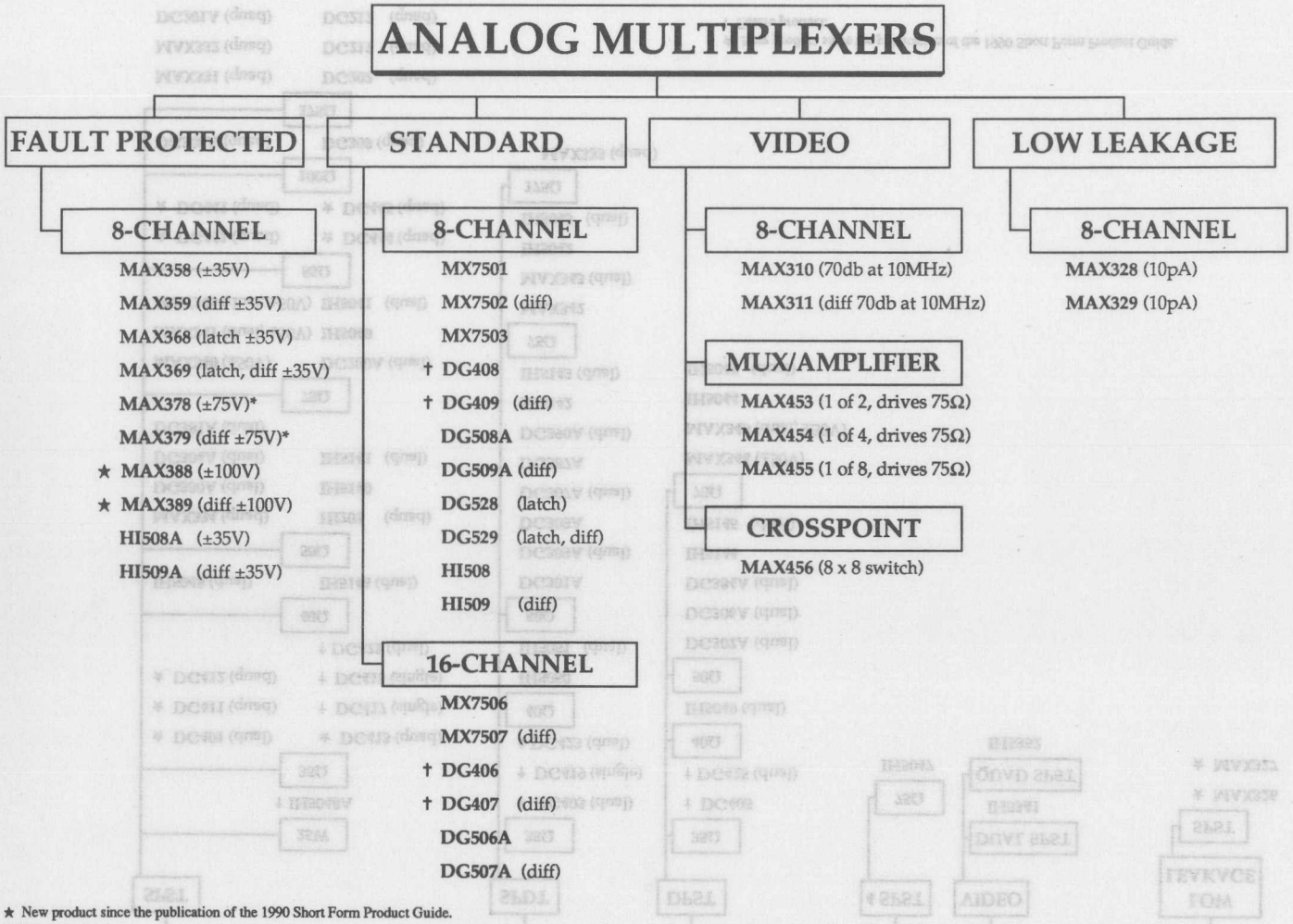
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ANALOG SWITCHES



★ New product since the publication of the 1990 Short Form Product Guide.
† Future product.

ANALOG MULTIPLEXERS



★ New product since the publication of the 1990 Short Form Product Guide.
† Future product.
* Withstands quoted input or output voltage indefinitely with/without supply voltage present.